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# JOURNAL OF PALEONTOLOGY

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## PLIOCENE AND MIOCENE FORAMINIFERA FROM THE CAPISTRANO FORMATION, ORANGE COUNTY, CALIFORNIA


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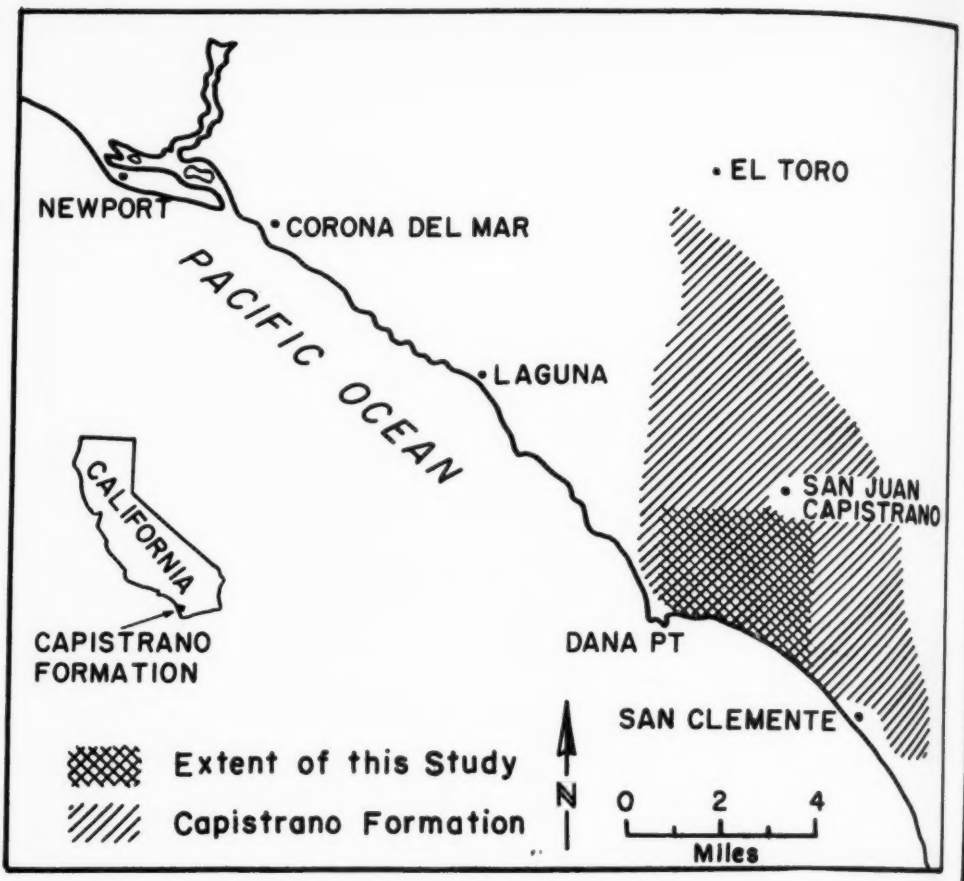
ABSTRACT—Fifty-nine species and varieties of Foraminifera are recognized and figured from the Capistrano formation, Orange County, California. Of these, two new species and four new varieties are described, and one new name is suggested. Siltstones and shales comprising the lower portion of the Capistrano formation are shown to contain foraminiferal assemblages belonging to the upper Mohnian stage of the Miocene. The upper portion of the formation, which for the most part is composed of sandy siltstones, contains foraminiferal faunas similar to those in the upper part of the Repetto formation (lower Pliocene) of the Los Angeles Basin. Evidence is advanced to support the conclusion that the assemblages typical of the middle and lower portion of the Repetto are not represented due to biofacies peculiarities rather than missing strata.


### INTRODUCTION

THE sediments considered in this study comprise the Capistrano formation, located in the vicinity of the city of San Juan Capistrano, California, and were first described in print by Woodford in 1925 as a part of his investigation of the San Onofre Breccia. The formation crops out along the coast for the entire distance between Dana Point and San Clemente, and extends inland for nearly seven miles (Text-fig. 1). The Capistrano formation was originally described as thin-bedded dark gray shales, and was said to contain beds of fine sandstone, usually high in quartz and sometimes feldspathic, with the sand predominating at the top of the formation. At the time these sediments were named, there was very little paleontologic evidence upon which to base a definite age assignment. Megafossils found in the region were indicative of the Pliocene, but there was a possibility that these remains actually had come from younger overlying beds. Diatoms found in the lower shales and siltstones suggested an upper Miocene age for these rocks, and were correlated with the diatoms of the upper Miocene deposits near Monterey, California. The formation was thus given an age of possible upper Miocene or lower Pliocene. The present study of the Foraminifera of the Capistrano formation was begun in 1950 in an attempt to gain additional and more conclusive evidence for an age assignment. One hundred sixty scattered outcrop samples were collected in the area near San Juan Capistrano, but only a small percentage yielded Foraminifera. Because of the lack of diagnostic microfossils in most of the samples, a complete vertical section could not be studied; however, diagnostic faunal assemblages were obtained from both the


[1] Acknowledgment is made to the management of The Texas Company for permission to publish this paper.




TEXT-FIG. *1*—Generalized location of the Capistrano formation, showing the area considered in this investigation (adapted from Woodford, 1925).

lower and upper portions of the formation (White, 1952).

I wish to express my sincere appreciation to Dr. O. L. Bandy of the University of Southern California for first calling my attention to the problem, as well as for his continuous helpful suggestions while the study was in progress. Many thanks are also due to J. M. Hamill of The Texas Company, W. H. Holman of the Standard Oil Company of California, Boris Laiming of The Texas Company and Dr. A. O. Woodford of Pomona College for their suggestions, and to Miss Ruth Todd of the United States National Museum, and to Dr. Brooks Ellis of the American Museum of Natural History for comparing several specimens with the types.

## HISTORICAL REVIEW

Previous work in the region around San Juan Capistrano has been very limited. The southern-most portion of the State was included in several of the early geological reports by Goodyear (1890), Fairbanks (1893), Watts (1900), McLaughlin and Waring (1914), Ellis and Lee (1919), and Vander Leck (1921), but until 1925 there was no attempt to investigate the rocks in the area under discussion.

In 1925, Woodford, in connection with a study of the San Onofre breccia, described the lithology of the sediments and gave them the name Capistrano formation. At that time no detailed map of the entire formation was given, although the general extent was shown on a small-scale geologic

map. Since the publication of Woodford's paper on the San Onofre breccia, the region has been entirely neglected by subsequent authors except for the following excerpts: Reed (1933, p. 238) states that, "Woodford's 'Capistrano Formation,' is now known to be at least in part lower Pliocene (Repetto) in age. . . ." Reed & Hollister (1936, p. 125) briefly mention the Capistrano region in noting that the Pliocene Los Angeles Basin "was the apical part of the Tertiary Capistrano embayment." Kleinpell (1938, p. 168), in discussing the lower Pliocene strata of California, points out that the major part of the Capistrano formation probably should be referred to the lower Pliocene. Driver (1948, p. 116) mentions very briefly that sediments of both Miocene and Pliocene age are present near San Juan Capistrano.

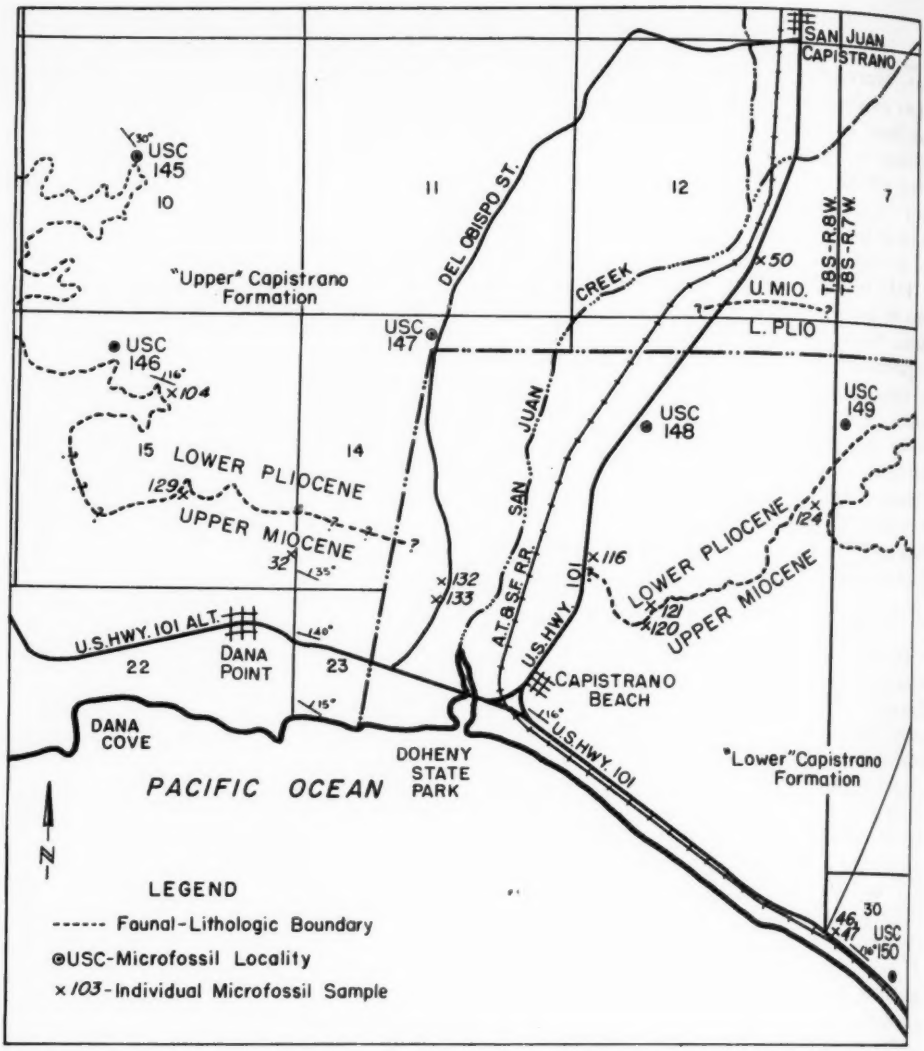
### THE CAPISTRANO FORMATION

Two distinct foraminiferal assemblages were found within the Capistrano formation, and each of these faunas is restricted to a sedimentary unit which usually is distinguishable from the other in the area under consideration in this report. The lower part of the formation is composed of over 1500 feet of well-consolidated fractured siltstones and some shale beds, with sands developed near the base. For convenience this part of the formation will be referred to as the lower Capistrano. The overlying 300 to 400 feet of somewhat lighter-colored, loosely consolidated siltstones and sands will be referred to as the upper Capistrano (Text-fig. 2).

*Lower Capistrano.*—The lower Capistrano rests directly on the Monterey shale, and according to Woodford (1925, p. 216), the contact is conformable or nearly so. This part of the formation is well exposed along U. S. Highway 101 between Dana Point and San Clemente, where it forms a steep bluff along the northeast side of the road. Scattered outcrops throughout the area show that for the most part the lower Capistrano is composed of dark to medium brown, well consolidated but highly fractured siltstone which exhibits a hackly texture on freshly broken surfaces. Beds of shale occur locally within this siltstone, and limestone nodules or lenses are common at some horizons. Relatively large amounts of sulphur and gypsum were noted at many of the outcrops. A breccia and coarse sandstone is exposed at the extreme western edge of Doheny State Beach, which Woodford (1925, p. 216) placed at the base of the Capistrano formation. The sand grades upward into finer sediments, becoming inter-bedded with shales and then eventually giving way to the typical siltstone which comprises the greater part of the lower Capistrano formation.

Although abundant remains of diatoms, radiolaria and sponges are present throughout the siltstone, Foraminifera are entirely lacking except at one horizon. A number of small specimens of a thin-shelled mollusc, *Hyalopecten peckhami* (Gabb), occur at one point in a shale bed which corresponds to USC Locality 150. Several samples from the bluff along U. S. Highway 101 (USC Locality 150) yielded abundant Foraminifera, but these fossiliferous zones were limited to a fifteen foot bed of brown, thinly laminated diatomaceous shale which weathers almost to white. This foraminiferal stratum is approximately 600 feet below the lowest occurrence of a Pliocene assemblage. No Foraminifera were recovered from this 600 foot interval of siltstone, but the diatoms, radiolaria and sponge spicules which are so typical of the lower unit of the Capistrano formation are present throughout.

The foraminiferal fauna which occurs at this point in the Capistrano formation is rather difficult to classify, in that it has affinities to both the Mohnian and the Delmontian stages of the upper Miocene. Table 1 lists the species present and shows their frequency and distribution in the Miocene of California as given by Kleinpell (1938), and Woodring, Bramlette & Kew (1946, p. 36–39). This table shows that the majority of the previously reported species are long-ranged and are found in both the lower Delmontian and the Mohnian, but two individuals, *Bolivina bramlettei* and *Bolivina decurtata* are not reported above the Mohnian. The presence of these two species in the assemblage suggests that the fauna should be considered Mohnian. The relatively large number of species of *Bolivina* present at this locality contributes additional evidence for the Mohnian, as that stage contains numer-




TEXT-FIG. 2—Generalized map showing the distribution of the Miocene and Pliocene units of the Capistrano formation south of San Juan Capistrano, California. For clarity, a thin veneer of Pleistocene terrace material which extends along the coast has been omitted. Base map adapted from the Dana Point Quadrangle, U. S. Geol. Survey, 1949.

## EXPLANATION OF PLATE 27

FIG. *1*—*Siphotextularia flintii* (Cushman), ×70. *a*, side view; *b*, apertural view.

*2,3*—*Marginulinopsis capistranoensis* White, n. sp. *2*, holotype, ×38. *a*, side view; *b*, apertural view; *c*, edge view. *3*, paratype, ×38. *a*, side view; *b*, apertural view; *c*, edge view.

*4,5*—*Glandulina laevigata* d'Orbigny, ×63. *4*, side view, uniserial form; *5*, *a*, side view, biserial form; *b*, apertural view, biserial form.

*6*—*Marginulinopsis capistranoensis* White, n. sp. Paratype, X31. Side view.

*7*—*Lagena alcocki* White, n. name, ×100. *a*, side, view; *b*, apertural view.

*8*—*Robulus cushmani* Galloway & Wissler, ×38. *a*, edge view; *b*, side view.

*9*—*Nonion pompilioides* (Fichtel & Moll), ×63. *a*, edge view; *b*, side view.

*10*—*Nonionella miocenica* Cushman, ×76. *a*, dorsal view; *b*, edge view; *c*, ventral view.

*11*—*Pullenia malkinae* Coryell & Mossman, ×70. *a*, side view; *b*, peripheral view.

1b

2b

3b

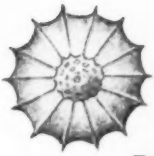
3c

1a

2c

2a

3a


7b

4

5b

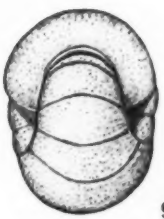
6

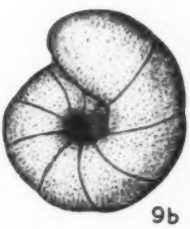
7a

5a

8a

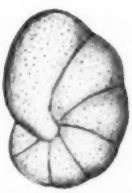
8b


9a


9b

10a

10b


10c

11a

11b

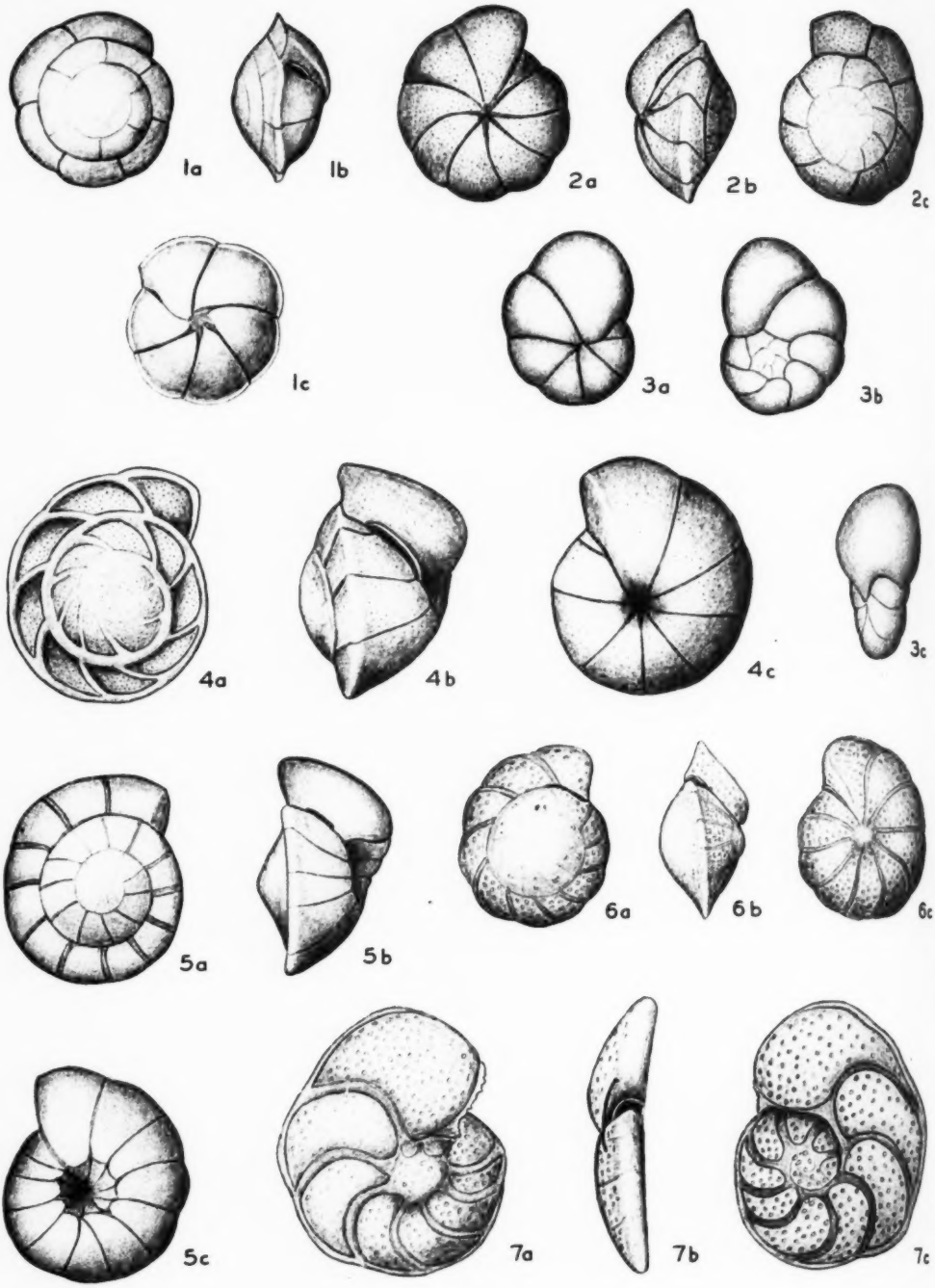

1a
1b
2a
2b
2c
1c
3a
3b
4a
4b
4c
3c
5a
5b
6a
6b
6c
5c
7a
7b
7c

TABLE 1.—DISTRIBUTION OF LOWER CAPISTRANO FORAMINIFERA IN THE UPPER MIOCENE

Abundance of specimens in the Capistrano formation:
A—abundant C—common R—rare
X—reported distribution in California

| | Capistrano | Upper Miocene | | | |
|---|---|---|---|---|---|
| | | U. Delm. | L. Delm. | U. Mohn. | L. Mohn. |
| *Bolivina bramlettei* | R | | | X | |
| *B. decurtata* | R | | | X | X |
| *B. foraminata* | A | X | X | X | X |
| *B. pocheensis* | C | | | | |
| *B. seminuda humilus* | C | | | | |
| *B. sinuata* | R | X | X | X | |
| *Buliminа pagoda hebespinata* | R | | | | |
| *Buliminella curta* | A | X | X | X | X |
| *B. subfusiformis* | A | | X | X | X |
| *Cassidulina cushmani* | C | | | | |
| *Epistominella pontoni californica* | C | | | | |
| *E. smithi* | R | | | | |
| *Uvigerina hootsi* | C | | X | X | X |
| *U. segundoensis* | C | | X | X | X |
| *Valvulineria araucana* | R | | X | X | X |
| Total | 15 | 3 | 7 | 9 | 7 |

ous representatives of the genus, whereas its members are usually less common in the Delmontian. There is no denying that the fauna is closely related to the younger stage, however, and this fact, in addition to the lack of other species which are limited to the Mohnian, leads the author to the conclusion that the assemblage should be placed in the uppermost part of the Mohnian stage. It should be noted that Locality 150 falls within the upper part of the section of Miocene Capistrano, and no Foraminifera were found in the siltstones and shales either at the top or at the base; thus, the evidence of upper Mohnian at this horizon does not exclude the possibility that somewhat older Mohnian assemblages could be present within the unit. Also, it is possible that typical Delmontian may be present higher in the section, although no such faunal evidence was found.

A possible correlative unit occurs at Malaga Cove approximately 50 miles to the northwest, where the Malaga mudstone member of the Monterey shale is well exposed. The Malaga mudstone is lithologically identical to parts of the lower Capistrano and contains abundant radiolaria, diatoms and sponge spicules similar to those of the Capistrano formation. The only recorded Foraminifera are from localities 23, 24, and 25 of Woodring, Bramlette & Kew (1946) which are more typically Delmontian, however, than the assemblages from USC Locality 150. The possibility that these two units are equivalent at least in part is worthy of consideration, since at this time several hundred feet of upper Miocene sediments above USC Locality 150 have not as yet yielded Foraminifera, and could conceivably contain assemblages with a younger aspect than those thus far encountered.

*Upper Capistrano.*—The upper Capistrano beds directly overlie the consolidated siltstone described previously, and are typically composed of a loosely consolidated, light brown to gray, micaceous, siltstone. Near the base this unit is better lithified and in some areas even exhibits fracturing, making it difficult to distinguish from the under-

EXPLANATION OF PLATE 28

FIG. 1—*Eponides tener* (Brady), ×59. *a*, dorsal view; *b*, edge view; *c*, ventral view.
2—*Eponides subtener* (Galloway & Wissler). ×59. *a*, ventral view; *b*, edge view; *c*, dorsal view.
3—*Valvulineria araucana* (d'Orbigny), ×80. *a*, ventral view; *b*, dorsal view; *c*, edge view.
4—*Gyroidina altiformis* R. E. & K. C. Stewart, ×65. *a*, dorsal view; *b*, edge view; *c*, ventral view.
5—*Gyroidina soldanii multilocula* Coryell & Mossman, ×65. *a*, dorsal view; *b*, edge view; *c*, ventral view.
6—*Cibicides mckannai* Galloway & Wissler, ×63. *a*, dorsal view; *b*, edge view; *c*, ventral view.
7—*Planulina ornata* (d'Orbigny), ×63. *a*, ventral view; *b*, edge view; *c*, dorsal view.

lying Miocene sediments. The contact appears gradational in most of the area investigated, except at one point near the mouth of Deep Canyon at Capistrano Beach where the lower Capistrano siltstone abruptly gives way to a poorly consolidated sandy siltstone. The upper portion of the formation is well exposed in several ravines about one mile inland due north of Dana Point (USC Localities 145 and 146). Several artificial outcrops have been formed by road cuts along Del Obispo Street on the west side of San Juan Creek (USC Locality 147), and along U. S. Highway 101 on the east side of the creek (USC Locality 148). Poor exposures are offered by cuts along a ranch road (USC Locality 149) approximately 8/10 of a mile east of USC Locality 148. Scattered individual samples were also collected throughout the area, and those containing diagnostic Foraminifera are shown on the accompanying map (Text-fig. 2).

Foraminifera, although not widespread, are usually very abundant when present. Diatoms, radiolaria, and sponge spicules are practically nonexistent in this upper portion of the Capistrano formation. The foraminiferal assemblages present at USC Localities 145 through 149 are comparable to faunas found in the upper part of the Repetto formation in the central part of the Los Angeles Basin, and contain representatives of one or more of the following typical Repetto species: *Bolivina subadvena sulphurensis, Bulimina rostrata, Bulimina subcalva, Nonion*

TABLE 2.—INDIVIDUAL FOSSILIFEROUS SAMPLES NOT INCLUDED WITHIN USC LOCALITIES 145 TO 150. SEE TEXT- FIG. 2 FOR LOCATIONS

| Sample Number | Fossil remains | Age |
|---|---|---|
| 32 | sponge spicules, diatoms, radiolaria | upper Miocene |
| 46 | foraminifera | upper Mohnian |
| 47 | foraminifera | upper Mohnian |
| 50 | sponge spicules, radiolaria | upper Miocene |
| 104 | foraminifera | lower Pliocene |
| 116 | foraminifera | lower Pliocene |
| 120 | sponge spicules, diatoms, radiolaria | upper Miocene |
| 121 | foraminifera | lower Pliocene |
| 124 | sponge spicules, diatoms, radiolaria | upper Miocene |
| 129 | sponge spicules | upper Miocene |
| 132 | sponge spicules, radiolaria | upper Miocene |
| 133 | sponge spicules, radiolaria | upper Miocene |

TABLE 3.—DISTRIBUTION OF PLIOCENE FORAMINIFERA IN THE UPPER CAPISTRANO FORMATION

A—abundant C—common R—rare

| USC Localities | 145 | 146 | 147 | 148 | 149 |
|---|---|---|---|---|---|
| *Angulogerina hughesi* | C | R | | | R |
| *Bolivina acuminata* | | C | | | C |
| *B. argentea* | | A | R | | R |
| *B. semiperforata* | C | | | | |
| *B. sinuata* | | C | R | C | R |
| *B. subadvena sulphurensis* | C | R | | A | |
| *Bulimina affinis* | R | | R | R | |
| *B. denudata deformata* | | R | R | R | C |
| *B. rostrata* | R | R | | R | |
| *B. subacuminata* | R | C | R | C | |
| *B. subcalva* | | R | C | | |
| *Buliminella curta* | R | R | R | C | R |
| *B. subfusiformis* | R | R | R | C | R |
| *Cassidulina californica* | C | R | R | C | A |
| *C. cushmani* | C | C | R | A | R |
| *C. laevigata carinata* | | | | R | |
| *C. lomitensis* | R | R | | R | A |
| *C. transluscens* | C | R | R | R | C |
| *Cassidulinoides cornuta* | | R | R | | |
| *Chilostomella czizeki* | R | | | | |
| *Cibicides mckannai* | C | R | R | R | C |
| *Ehrenbergina compressa* | | | R | R | |
| *Epistominella bradyana* | A | A | A | A | A |
| *E. smithi* | R | R | R | A | |
| *Eponides subtener* | | | R | R | R |
| *E. tener* | R | | R | R | |
| *Glandulina laevigata* | R | | R | | R |
| *Globobulimina pacifica curtata* | R | R | R | R | R |
| *Gyroidina altiformis* | | | R | | |
| *G. soldanii multilocula* | R | R | | R | |
| *Lagena alcocki* | R | | R | | R |
| *Marginulinopsis capistranoensis* | R | | | | R |
| *Nonion pompilioides* | | | R | R | |
| *Nonionella miocenica* | | | R | | R |
| *Orbulina universa* | R | R | R | R | R |
| *Planulina ornata* | R | R | R | | R |
| *Plectofrondicularia advena* | R | R | R | R | R |
| *P. californica* | | R | R | R | R |
| *Pullenia malkinae* | R | R | R | R | R |
| *Robulus cushmani* | R | | R | R | R |
| *Siphonodosaria advena* | R | R | R | R | R |
| *S. lepidula* | R | R | C | R | R |
| *Siphotextularia flintii* | | | R | R | |
| *Uvigerina hispida* | R | R | R | R | R |
| *U. hispidocostata* | R | R | A | | R |
| *U. hollicki* | | R | | R | R |
| *U. kernensis subcalva* | | C | | R | |
| *U. peregrina* | R | C | A | R | C |
| *U. senticosa adiposa* | R | C | | C | |
| *Valvulineria araucana* | R | | R | R | R |
| *Virgulina nodosa* | | R | R | R | R |

*pompilioides* and *Plectofrondicularia californica*. Table 3 lists all species, and shows their distribution at the five previously mentioned localities.

## PALEOECOLOGY

*Upper Miocene. USC Locality 150.*—The assemblage of Foraminifera found in the bluff overlooking U. S. Highway 101 south of Capistrano Beach (USC Locality 150), is considered to belong to the uppermost part of the Mohnian stage of the California Miocene. Drawing paleoecologic conclusions based on the environmental habits of species which are still living today obviously becomes increasingly difficult in proportion to the age of the fossil assemblage to be considered. Only four of the species present at this locality are reported living off the coast of California.

The fauna from this locality is dominated by two closely related species of *Buliminella, B. curta* and *B. subfusiformis*, which comprise approximately 78 per cent of the entire assemblage. *B. curta* is not recorded by Natland (1933) in his study of Recent Foraminifera from off this coast, although *B. subfusiformis* was encountered. The known close association of these two forms in other areas indicates similar environmental habits, and thus they will be considered together for the purposes of this study. *Cassidulina cushmani, Epistominella smithi* and *Valvulineria araucana*, which together compose less than two per cent of the assemblage, were reported from the Pacific Ocean by Natland (1933) and Bandy (1953) in their investigations of Recent Foraminifera. None of the other species are known to exist in our present oceans. The depths of water preferred by these four species as shown by the two previously mentioned authors are: *Buliminella subfusiformis* (*B. curta*), 1700′ to 2200′; *Cassidulina cushmani*, 920′ to 5400′; *Epistominella smithi*, 1800′ to 2400′; *Valvulineria araucana*, 2000′ to 2800′. With the exception of *C. cushmani*, which has a rather wide tolerance, all indicate a similar preference as to depth of water with the average between 2000 and 3000 feet.

*Lower Pliocene. USC Localities 145 to 149.*—Assemblages from USC Localities 145 to 149 are lower Pliocene in age and correlate with faunas in the upper Repetto formation (upper part of the lower Pliocene) of the Los Angeles Basin.

An examination of the species' depth distribution off California as given by Natland (1933), Crouch (1952) and Bandy (1953) is revealing. The majority of species show a preference for waters ranging in depth from 900 to 3000 feet, with the average between 2000 and 3000 feet. A small number are found inhabiting deeper zones below 4000 feet. The latter, incidentally, include the species which are most diagnostic of the Repetto, but this is not inconsistent with their occurrence elsewhere, as they seem to be widely distributed throughout the lower Pliocene, regardless of supposed depositional depths. With so wide a range of preferences, an average of the depths for all individuals could not be expected to give a very accurate figure for the deposition of these assemblages. Inasmuch as most of the species are typical of the shallower water, they could be considered as indicating the sedimentary environment of the Pliocene part of the Capistrano formation. However, the few individuals present which are usually found living well below 4000 feet might be considered indicative of an environment at least as deep as 4000 feet, as their association with the much more abundant shallow water Foraminifera may be due in part to the displacement of some shallower types into deeper water. Considering both aspects of the foregoing, 2000 to 4000 feet seems a conservative estimate of water depth for these sediments. A consideration of these presumed environmental preferences and the presence of several well established Repetto markers leads to the conclusion that paleoecologically, the Pliocene part of the Capistrano formation is equivalent to the upper portion of the Repetto formation of the central Los Angeles Basin.

## RELATIONSHIP OF THE UPPER AND LOWER CAPISTRANO

Included within the boundaries of the Capistrano formation are sediments containing both Miocene and Pliocene foraminiferal assemblages. Of vast importance, and certainly worthy of considerable attention is the fact that there is no faunal evidence of the lowermost portion of the Plio-

cene (middle and lower Repetto formation equivalents). Of secondary importance is the missing Delmontian stage of the upper Miocene, although this may possibly be represented in time at least, by the non-foraminiferal silts overlying the Mohnian horizon. The apparent absence of a continual faunal sequence within the formation might be explained in several manners, the more likely of which are an unconformity, a depositional interruption, or biologically, as some environmental control acting upon the foraminiferal population at the time of deposition. Each of these is discussed below and all evidence, both favorable and unfavorable, is presented for each.

In the opinion of Driver (1948, p. 116), the Miocene and Pliocene sediments of this area are separated by an unconformity. This explanation is certainly readily adaptable to the paleontological findings, and would easily explain the apparent absence of as much as 1000 feet or more of sediments. Structural evidence in support of this explanation is not present, however. No erosional break was found, but rather on the contrary, the lithology both above and below the contact denotes a gradation rather than a definite break. A common occurrence of molluscan fragments (predominantly Pectinidae) at USC Locality 149 could be considered evidence of shallow, near shore waters, and hence suggestive of an unconformity, except that the Foraminifera from this same horizon indicate deeper seas ($\pm$3000 feet). Under these circumstances it is logical to assume that the molluscs which prefer a shallow water environment were transported either by current action or turbidity flows to depths greater than their normal habitat. Although the presence of an unconformity is the easiest explanation of the faunal break, there is no reasonable paleoecological or structural evidence to support such a conclusion.

Numerous authors throughout the world have reported instances of present-day ocean bottoms which lack any Recent sediments due to the sweeping action of currents. In these cases the exposed bottom rocks range from Cretaceous or older to Pleistocene, so that such a break between Miocene and Pliocene sediments is certainly feasible. However, the possibility that such a submarine unconformity, or lack of deposition, could be responsible for the break in foraminiferal sequence in the Capistrano formation is remote. Such areas of non-deposition are usually submarine highs, which, although often at great depths, are continually subjected to relatively strong current action. Revelle & Shepard (1939), in discussing sedimentation off the California coast, note that areas where submarine unconformities are developed are characterized by rocky outcrops and sediments of uneven texture. When far from shore, these areas have Foraminifera, calcareous fragments and glauconite as the chief constituents of the bottom veneer, since all the fine clastic material is removed by the currents. The very nature of the Pliocene-Miocene boundary within the Capistrano formation rules out the application of a submarine unconformity. No evidence of submarine erosion or of relatively coarse, poorly sorted clastic material was encountered at the top of the upper Miocene sediments, either adjacent to or directly at the contact. On the contrary, the formation exhibits a gradual change from a highly fractured, well consolidated siltstone, to a less indurated and more sandy siltstone as the Miocene-Pliocene boundary is crossed. Furthermore, no glauconite is present either in the Miocene or Pliocene, and calcareous fragments are lacking except at USC Locality 149 as previously mentioned. A period of non-deposition of the magnitude required to account for the missing middle and lower Repetto type faunas certainly could be expected to leave some record in the rocks involved. The lack of any significant evidence of depositional interruption suggests further consideration of the theory is unnecessary.

Studies of Recent Foraminifera have shown that faunas vary in accordance to their environmental influences such as depth, temperature, salinity, etc. These factors appear to become of greater importance, causing more noticeable changes in the population, in the waters of medium and shallow depths. Reports by Natland (1933), Crouch (1952) and Bandy (1953) on Recent Foraminifera off the California coast have shown a decided link between the fossil assemblages of the southern California

Pliocene and the living assemblages found at varying depths in today's ocean. In general, it has been demonstrated that deep water living faunas are similar to the older Pliocene faunas, and that the shallower water living faunas have affinities for younger fossil assemblages. The previous discussion of paleoecology, which indicated the water depths of the upper Capistrano Foraminifera to be between 2000 and 4000 feet, offers two possibilities for a locale of deposition which could be responsible for a misleading foraminiferal fauna.

The Capistrano area is located on the outskirts of the large Los Angeles basin which received thousands of feet of sediments during the late upper Miocene and Pliocene. During the lower Pliocene the central portion of the basin is thought to have been well over 5000 feet deep with depths reaching closer to 7000 feet or more in the early stages of deposition. The Pliocene Capistrano formation being on the edge of this basin would have been deposited in shallower water than contemporary sediments nearer the center. Thus, the formation could be expected to contain "young" shallower water foraminiferal faunas equivalent in age to the deeper and older appearing assemblages of the central basin area. A second possibility is that the Capistrano deposition actually was limited to a separate basin having a relatively shallow sill depth. Crouch (1952) found that in such basins the foraminiferal population was governed by the depth of the sill, and that the assemblages did not change with depth below this feature. This was attributed to the almost constant temperature (regardless of depth) which occurs in the basins below their sills. In this case the basin of deposition of the upper Capistrano would have had a sill depth ranging somewhere between 2000 and 4000 feet, which would thus have given the assemblages their "young" aspect, although the deposition took place in the early Pliocene.

Regardless of which of these two explanations is preferred, the results are the same. Both account for the foraminiferal assemblages' variation from the typical lowermost Pliocene faunas found elsewhere. The conclusion that these assemblages are absent either by lateral variation within a single basin, or through control by a basin sill, is not offered as the only alternative. It is considered to be the most likely explanation for the apparently missing Pliocene strata.

## CONCLUSIONS

1. Foraminiferal assemblages found within the Capistrano formation indicate that rocks of both upper Miocene and lower Pliocene age are included within its boundaries. The upper part of the formation, which is lower Pliocene, contains a fauna similar to the upper Repetto formation of the Los Angeles Basin, and the fauna from the lower part of the Capistrano is believed to belong to the uppermost part of the Mohnian stage of the Miocene.

2. The lithologic characters of the Miocene and Pliocene units, although quite similar in some areas, typically display enough individuality to allow them to be distinguished throughout the area studied. The Miocene siltstones are dark to medium brown, well consolidated and highly fractured, whereas the Pliocene siltstones are usually somewhat lighter in color, less consolidated and are sandier than the older sediments.

3. The change in lithology from the Miocene to Pliocene is gradational in most of the area.

4. Deposition is thought to have been continuous across the Miocene-Pliocene boundary, with a water depth of $\pm 3000$ feet.

5. No foraminiferal evidence of the Delmontian stage was found, but a 600 foot interval at the top of the Miocene may represent this stage.

6. Biofacies variations are considered as the most likely explanation for the missing lowermost Pliocene (middle and lower Repetto formation equivalents) foraminiferal assemblages.

## SYSTEMATICS

Many of the species common in the Los Angeles Basin area which are represented in this study were figured, and more nearly complete synonomies and descriptions given by Martin (1952). The Capistrano forms were compared with Martin's hypotypes, and, in those cases where the species are

identical, the descriptions are omitted and the synonomies are shortened to avoid needless repetition.

All holotypes and hypotypes are deposited in the paleontological collection of the University of Southern California, Los Angeles, California. The figures were drawn by the author.

Family TEXTULARIIDAE d'Orbigny, 1826
Genus SIPHOTEXTULARIA Finlay, 1939
SIPHOTEXTULARIA FLINTII (Cushman)
Pl. 27, fig. 1a,b

*Textularia flintii* CUSHMAN, 1911, U. S. Nat. Mus., Bull. 71, p. 21, fig. 36a,b; Recent, Guam. CUSHMAN, 1921, U. S. Nat. Mus., Bull. 100, vol. 4, p. 113–114, pl. 22, fig. 4; Recent, Atlantic. CUSHMAN, STEWART & STEWART, 1930, Trans. San Diego Soc. Nat. Hist., vol. 6, p. 50, pl. 1, fig. 1a,b; Pliocene, California.
*Siphotextularia flintii* MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 117, pl. 17, fig. 1a–c; Pliocene, California.

In many of the specimens encountered in the Capistrano formation the aperture is situated diagonally in respect to the septal face of the last chamber. The development of this angle varies with the individual, but is well illustrated by the figured specimen.

*Hypotype.*—USC No. 3534, lower Pliocene.

Genus GLANDULINA d'Orbigny, 1839
GLANDULINA LAEVIGATA d'Orbigny
Pl. 27, fig. 4, 5a,b

*Nodosaria (Glandulina) laevigata* D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 252, pl. 10, fig. 1–3; type level not designated.
*Glandulina laevigata* CROUCH, 1952, Bull. Amer. Assoc. Petrol. Geol., vol. 36, p. 823, pl. 1, fig. 11; Recent, Pacific. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 118, pl. 17, fig. 3a,b; Pliocene, California. (See this reference for synonomy.)

Specimens showing a biserial stage in the early portion of their tests (Pl. 27, fig. 5) have been included in this category as they are identical to the characteristic individuals in all other respects.

*Holotype.*—USC No. 3516, lower Pliocene.

Genus LAGENA Walker & Boys, 1784
LAGENA ALCOCKI White, n. name
Pl. 27, fig. 7a,b

*Entosolenia williamsoni* ALCOCK, 1865, (*not Lagena williamsoni* Harvey & Bailey, 1854) Lit. Philos. Soc. Proc., vol. 4, p. 193; Recent, England.
*Lagena williamsoni* WRIGHT, 1876–77, Belfast Nat. Field Club Proc., appendix 4, p. 104, pl. 4, fig. 14. CUSHMAN, 1923, U. S. Nat. Mus., Bull. 104, p. 61, pl. 11, fig. 8,9; Recent, Irish Coast. CUSHMAN, 1927, Bull. Scripps Instit. Oceanography, Tech. Ser., vol. 1, p. 146; Recent, Pacific. CUSHMAN, 1929, Contr. Cushman Lab. Foram. Res., vol. 5, p. 70, pl. 11, fig. 7,8; Pliocene, California. CUSHMAN, STEWART & STEWART, 1930, Trans. San Diego Soc. Nat. Hist., vol. 6, p. 59, pl. 8, fig. 5; Pliocene, California. CUSHMAN, 1933, U. S. Nat. Mus. Bull. 161, p. 34, pl. 8, fig. 8; Recent, Pacific. BANDY, 1944, Jour. Paleo., vol. 18, p. 369, pl. 60, fig. 13; Eocene, Oregon. CUSHMAN & MCCULLOCH, 1950, Allan Hancock Pac. Exped., vol. 6, p. 362, pl. 48, fig. 14,15; Recent, Pacific Ocean. NATLAND, 1950, Geol. Soc. Amer., Memoir 43, pt. 4, p. 13, pl. 4, fig. 5; Pliocene, Carmen Island. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 122, pl. 18, fig. 10a,b; Pliocene, California.

Test unilocular, subglobular, and somewhat elongate, round in cross section, tapering inward from a wide rounded apical end; test is slightly constricted near the apertural end, which is marked by a reticulate area consisting of three rows of large pores; below this the wall is finely perforate and ornamented by about 14 high longitudinal costae; aperture is located at the end of a short tube-like neck just above the reticulate collar.

Since the name *Lagena williamsoni* Harvey & Bailey, 1854 preoccupies *Entosolenia williamsoni* Alcock, 1865, this new name is proposed in honor of the original author.

*Hypotype.*—USC No. 3520, lower Pliocene.

Genus MARGINULINOPSIS Silvestri, 1904
MARGINULINOPSIS CAPISTRANOENSIS
White, n. sp.
Pl. 27, fig. 2a–c, 3a–c, 6

Test elongate, early portion compressed and coiled, later chambers becoming rectilinear and inflated, until nearly circular in cross section; edge of coiled portion rounded but with a narrow keel which may extend upward onto the inflated chambers; sutures of the coiled part slightly curved, limbate, raised, with from 5 to 8 parallel elongate bosses giving a resemblance to costae; sutures in the later part becoming nearly straight, narrow and depressed; wall finely perforate, the uncoiled portion often with about 14 vertical costae which may be poorly developed; aperture radiate, terminal on

the periphery. Length of holotype (Pl. 27, fig. 2), 0.73 mm.

These forms show a wide variation in ornamentation as shown in the slightly raised bosses or costae of the holotype (Pl. 27, fig. 2), and the bold costae and bosses of the two paratypes (Pl. 27, fig. 3, 6). Individuals ranging between these two extremes are common; for that reason, all are considered to be the same species.

*Holotype.*—USC No. 3521, lower Pliocene, USC Locality 145.

*Paratypes.*—Fig. 3, USC No. 3567; fig. 6, USC No. 3568.

### Genus ROBULUS Montfort, 1808
### ROBULUS CUSHMANI Galloway & Wissler
Pl. 27, fig. 8a,b

*Robulus cushmani* GALLOWAY & WISSLER, 1927, Jour. Paleo., vol. 1, p. 51, pl. 8, fig. 11; Pleistocene, California. NATLAND, 1950, Geol. Soc. Amer., Memoir 43, pt. 4, p. 11, pl. 4, fig. 4; Pliocene, Carmen Island.

Test medium sized for genus, subcircular in side view, lenticular in edge view, periphery sharply keeled; chambers 7 in last whorl, uniform but gradually increasing in size as added; sutures widely limbate, slightly raised, nearly straight and joining in the center of the test to form a large umbo of opaque shell material; wall smooth, finely perforate; aperture radial, on the septal face of last chamber at the periphery, with a narrow straight opening extending downward on the face of the chamber for a short distance.

*Hypotype.*—USC No. 3531, lower Pliocene.

### Family NONIONIDAE Reuss, 1860
### Genus NONION Montfort, 1808
### NONION POMPILIOIDES (Fichtel & Moll)
Pl. 27, fig. 9a,b

*Nautilus pompilioides* FICHTEL & MOLL, 1798, Test, Micr., p. 31, pl. 2, fig. a–c; Recent, Mediterranean.

*Nonion pompilioides* CROUCH, 1952, Bull. Amer. Assoc. Petrol. Geol., vol. 36, p. 826, pl. 1, fig. 13,14; Recent, Pacific. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 123, pl. 19, fig. 2a,b; Pliocene, California. (See this reference for synonomy.) BANDY, 1953, Jour. Paleo., vol. 27, p. 177, pl. 21, fig. 12; Recent, Pacific.

*Hypotype.*—USC No. 3523, lower Pliocene.

### Genus NONIONELLA Cushman, 1926
### NONIONELLA MIOCENICA Cushman
Pl. 27, fig. 10a–c

*Nonionina auris* CUSHMAN, 1926, (*not* d'Orbigny), Contr. Cushman Lab. Foram. Res., vol. 1, p. 91, pl. 13, fig. 4a–c; Miocene, California.

*Nonionella miocenica* CUSHMAN, 1926, Contr. Cushman Lab. Foram. Res., vol. 2, p. 64; upper Miocene, California. CUSHMAN, STEWART & STEWART, 1930, Trans. San Diego Soc. Nat. Hist., vol. 6, p. 61, pl. 8, fig. 6a–c; Pliocene, California. CUSHMAN, 1939, U. S. Geol. Survey, Prof. Paper 191, p. 31, pl. 8, fig. 9; Miocene, California; Recent, off coast of Mexico. CUSHMAN & MCCULLOCH, 1940, Allan Hancock Pacific Exped., vol. 6, p. 161, pl. 18, fig. 1; Recent, Alaska to Costa Rica. BANDY, 1950, Jour. Paleo., vol. 24, p. 275, pl. 41, fig. 6a–c; middle or upper Pliocene, Oregon.

Test subcircular in side view, an elongate oval in marginal view, periphery broadly rounded, slightly lobulate; early coils partially visible on dorsal side, ventral side completely involute; chambers 8 to 9 in last whorl, uniform, gradually increasing in size as added, slightly inflated, last chamber with lobe extending to the umbilicus on the ventral side; sutures somewhat depressed, curved; wall smooth, finely perforate; aperture a slit on the periphery at the base of the last chamber extending along the lobe toward the ventral side.

*Hypotype.*—USC No. 3524, lower Pliocene.

### Genus PULLENIA Parker & Jones, 1862
### PULLENIA MALKINAE Coryell & Mossman
Pl. 27, fig. 11a,b

*Pullenia malkinae* CORYELL & MOSSMAN, 1942, Jour. Paleo., vol. 16, p. 234, pl. 36, fig. 3,4; Pliocene, Panama. NATLAND, 1950, Geol. Soc. Amer., Memoir 43, pt. 4, p. 35, pl. 9, fig. 14; Pliocene, Carmen Island. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 124, pl. 19, fig. 4a,b; Pliocene, California. (See this reference for synonomy.)

Some variation in thickness of the specimens was noted. The individual figured is less compressed than is typical of the species.

*Hypotype.*—USC No. 3529, lower Pliocene.

### Family ROTALIIDAE Reuss, 1860
### Genus VALVULINERIA Cushman, 1926
### VALVULINERIA ARAUCANA (d'Orbigny)
Pl. 28, fig. 3a–c

*Rosalina araucana* D'ORBIGNY, 1839, Voy. Amer. Merid., vol. 5, p. 44, pl. 6, fig. 16–18; Recent, Pacific.

*Valvulineria araucana* CUSHMAN, 1927, Bull. Scripps Inst. Oceanography, Tech. Ser., vol. 1, p. 160, pl. 4, fig. 7,8; Recent, Pacific. KLEINPELL, 1938, Miocene Strat. California, p. 307; Miocene, California. CUSHMAN, STEWART & STEWART, 1947, Oreg. Dept. Geol. and Min. Ind., Bull. 36, p. 20, pl. 3, fig. 1; Miocene, Oregon. CROUCH, 1952, Bull. Amer. Assoc. Petrol. Geol., vol. 36, p. 834, pl. 4, fig. 7,8; Recent, Pacific.

Test smaller than average for genus, subcircular in side view, nearly equally biconvex in edge view, periphery broadly rounded and moderately lobulate; chambers from 6 to 7 in last whorl with 2½ whorls visible on the dorsal side; sutures slightly depressed on both the dorsal and ventral sides, slightly curved dorsally, straight ventrally; last formed chamber extending into the umbo and forming a small flap; wall smooth with medium perforations; aperture a narrow slit at base of last chamber and extending under the flap on the ventral side.

Although the specimens from this area appear to agree with most previous authors' concepts of the species, it should be noted that d'Orbigny's original figure indicates a much thinner individual with a sharp periphery.

*Hypotype.*—USC No. 3543, upper Miocene; also occurs in lower Pliocene.

## Genus EPONIDES Montfort, 1808

### EPONIDES SUBTENER (Galloway & Wissler)

Pl. 28, fig. 2a–c

*Rotalia subtenera* GALLOWAY & WISSLER, 1927, Jour. Paleo., vol. 1, p. 60, pl. 10, fig. 4; Pleistocene, California.

*Eponides subtenerus* CROUCH, 1952, Bull. Amer. Assoc. Petrol. Geol., vol. 36, p. 834, pl. 5, fig. 6,7; Recent, Pacific.

*Eponides subtener* MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 124, pl. 19, figs. 6a–c; Pliocene, California. BANDY, 1953, Jour. Paleo., vol. 27, p. 177, pl. 23, fig. 8; Recent, Pacific.

*Hypotype.*—USC No. 3514, lower Pliocene.

### EPONIDES TENER (Brady)

Pl. 28, fig. 1a–c

*Truncatulina tenera* H. B. BRADY, 1884, Rep. Voy. Challenger, Zool., vol. 9, p. 655, pl. 95, fig. 11a–c; Recent, Atlantic, Pacific.

*Eponides tenera* CUSHMAN, 1927, Bull. Scripps Inst. Oceanography, Tech. Ser., vol. 1, p. 163, pl. 5, fig. 6,7; Recent, Eastern Pacific.

*Eponides umbonatus* CROUCH, 1952, Bull. Amer. Assoc. Petrol. Geol., vol. 36, p. 836, pl. 5, fig. 8,9; Recent, Pacific.

*Eponides tener* MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 124, pl. 19, fig. 7a–c; Pliocene, California. (See this reference for synonomy.) BANDY, 1953, Jour. Paleo., vol. 27, p. 177, pl. 23, fig. 3; Recent, Pacific.

This species is included in *Eponides umbonatus* (Reuss) by some authors but is set apart from that form by its slightly curved ventral sutures and the absence of a peripheral keel which appears in the type figure of Reuss and is absent in the figure of Brady.

*Hypotype.*—USC No. 3515, lower Pliocene.

## Genus GYROIDINA d'Orbigny, 1826

### GYROIDINA ALTIFORMIS R. E. & K. C. Stewart

Pl. 28, fig. 4a–c

*Gyroidina soldanii* var. *altiformis* R. E. & K. C. STEWART, 1930, Jour. Paleo., vol. 4, p. 67, pl. 9, fig. 2a–c; Pliocene, California.

*Gyroidina altiformis* BERMUDEZ, 1949, Special Publ. 25, Cushman Lab. Foram. Res., p. 251.

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### EXPLANATION OF PLATE 29

FIG. *1—Orbulina universa* d'Orbigny, ×58.

*2—Chilostomella czizeki* Reuss, ×59. *a*, side view; *b*, front view; *c*, top view.

*3—Bolivina acuminata* Natland, ×63. *a*, side view; *b*, apertural view.

*4—Bolivina argentea* Cushman, ×30. *a*, side view; *b*, apertural view.

*5,6—Bolivina bramlettei* Kleinpell. *5*, immature form, ×84. *a*, side view; *b*, apertural view. *6*, typical specimen, ×59.

*7—Bolivina decurtata* Cushman, ×59. *a*, side view; *b*, apertural view.

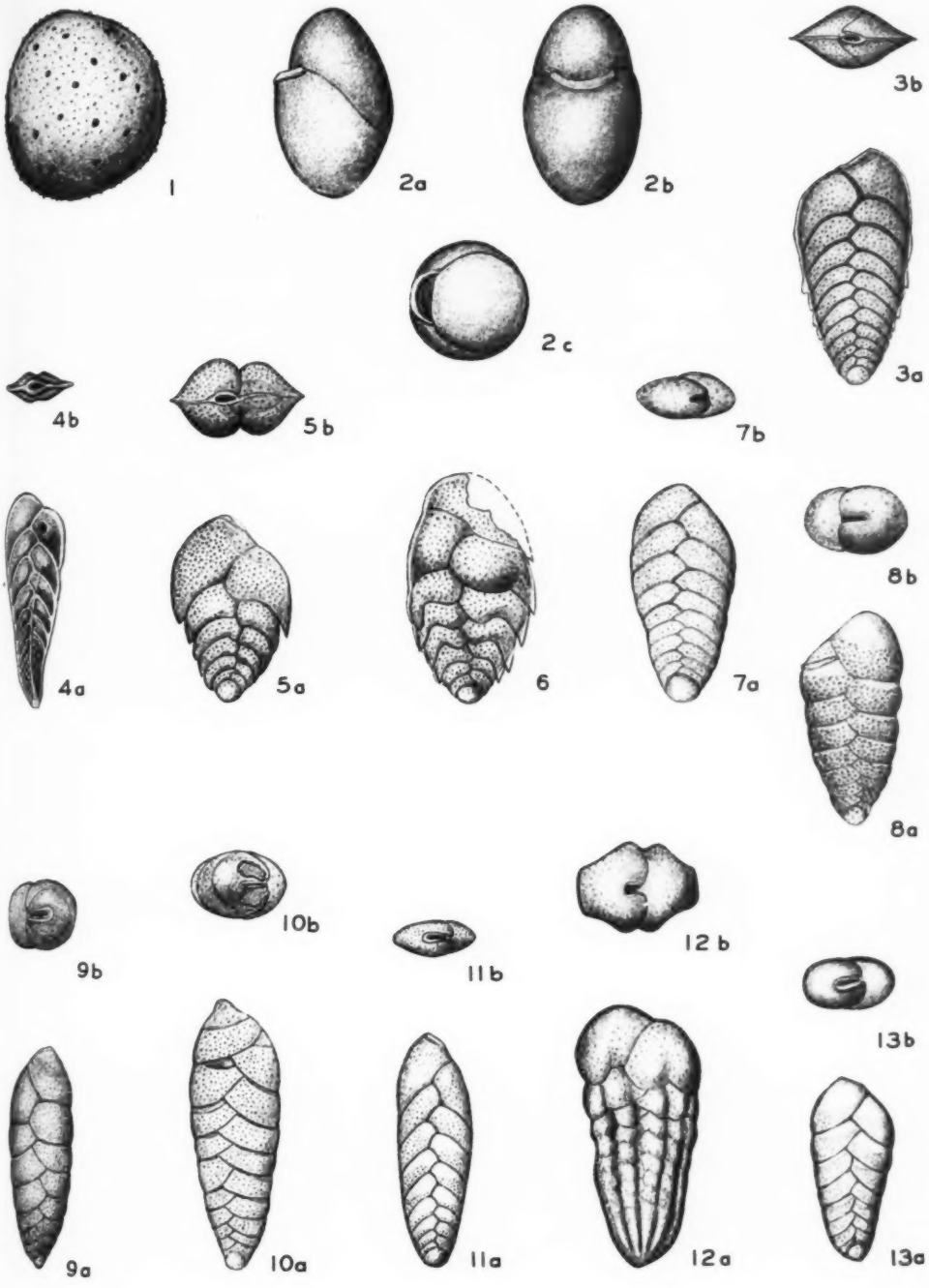
*8—Bolivina foraminata* R. E. & K. C. Stewart, ×56. *a*, side view; *b*, apertural view.

*9,10—Bolivina seminuda humilus* Cushman & McCulloch. *9*, poorly preserved, questionable form. ×56, *a*, side view; *b*, apertural view. *10*, typical form, ×52, *a*, side view; *b*, apertural view.

*11—Bolivina semiperforata* Martin, ×63. *a*, side view; *b*, apertural view.

*12—Bolivina sinuata* Galloway & Wissler, ×56. *a*, side view; *b*, apertural view.

*13—Bolivina pocheensis* White, n. sp. Holotype, ×76. *a*, side view; *b*, apertural view.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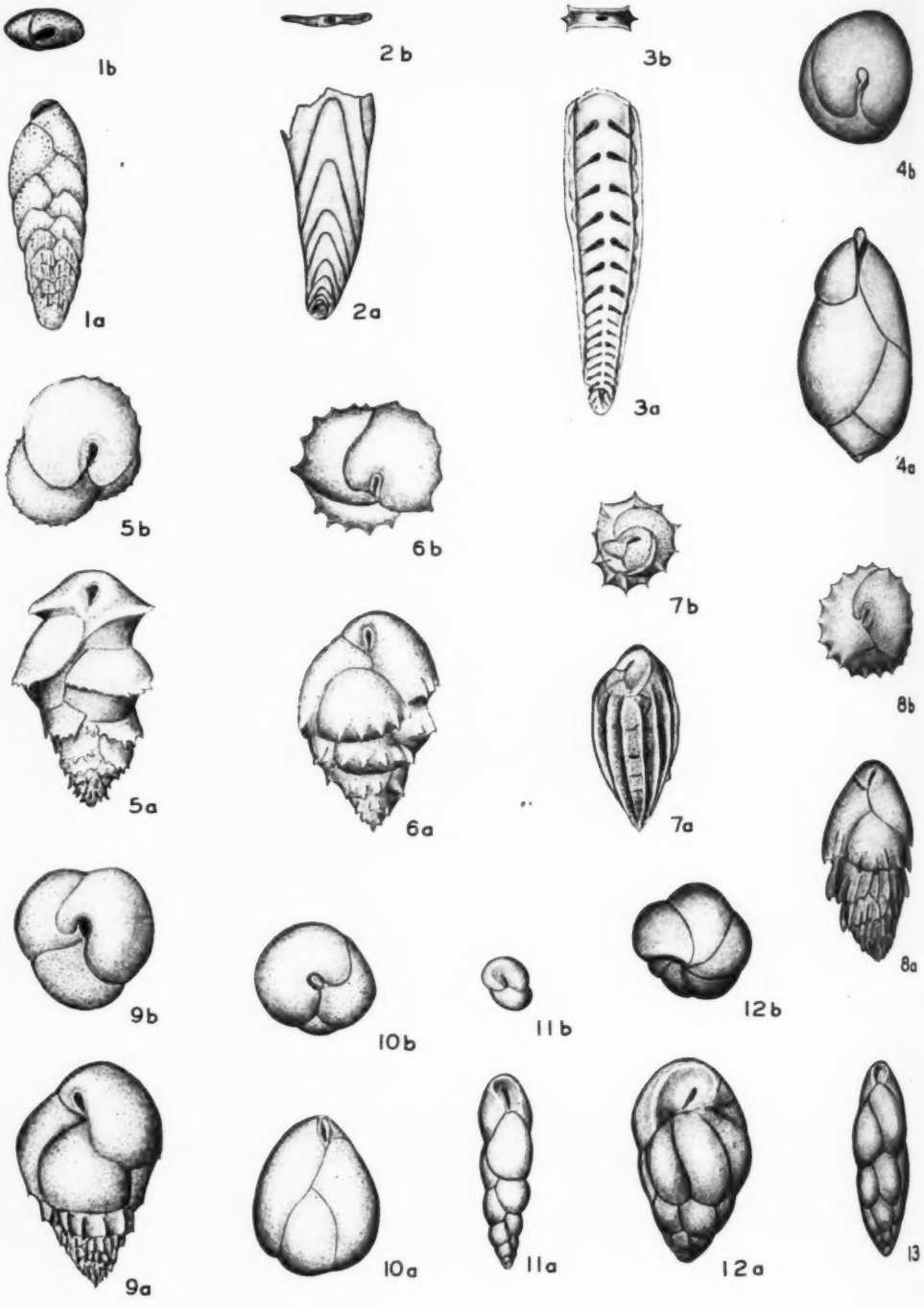
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12a
13

pl. 17, fig. 64–66; upper Oligocene, Dominican Republic. CROUCH, 1952, Bull. Amer. Assoc. Petrol. Geol., vol. 36, p. 834, pl. 4, fig. 10,11; Recent, Pacific. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 125, pl. 19, fig. 8a–c; Pliocene, California. (See this reference for synonomy.)

*Hypotype.*—USC No. 3518, lower Pliocene.

GYROIDINA SOLDANII MULTILOCULA
Coryell & Mossman
Pl. 28, fig. 5a–c

*Gyroidina soldanii* var. *multilocula* CORYELL & MOSSMAN, 1942, Jour. Paleo., vol. 16, p. 237, pl. 36, fig. 20; Pliocene, Panama. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 125, pl. 20, fig. 1a–c; Pliocene, California.

Test subacute in side view, unequally biconvex in edge view, dorsal side low, ventral side high, 3½ whorls visible on dorsal side, only last whorl seen on ventral; chambers 10 to 12 in last whorl, gradually increasing in size as added; sutures limbate and raised on dorsal side, raised slightly on ventral side, almost radial on both sides; ventral face with an extremely deep umbilicus in which the sutures are visible; wall smooth, very finely perforate; aperture a low arched opening at base of last chamber.

Specimens were compared with the holotype of *Gyroidina soldanii* var. *multilocula* by Brooks F. Ellis and found to belong to that variety although it was noted that the periphery of the Capistrano form is "somewhat sharper," and the central area of the evolute side is less distinct.

*Hypotype.*—USC No. 3519, lower Pliocene.

Genus CIBICIDES Montfort, 1808
CIBICIDES MCKANNAI Galloway & Wissler
Pl. 28, fig. 6a–c

*Cibicides mckannai* GALLOWAY & WISSLER, 1927, Jour. Paleo., vol. 1, p. 65, pl. 10, fig. 5,6; Pleistocene, California. CROUCH, 1952, Bull. Amer. Assoc. Petrol. Geol., vol. 36, p. 842, pl. 7, fig. 11,12; Recent, Pacific.

Test unequally biconvex with ventral side slightly more convex than the dorsal, edge sharp, periphery slightly lobate, from 9 to 10 chambers in the last whorl, with 4 whorls visible on the dorsal side, although secondary filling in the center of the test may obscure the early coils. A raised umbo usually is well developed on the ventral side; chambers uniform, gradually increasing in size, slightly inflated on the dorsal side, sutures limbate, dorsal sutures slightly curved in early portion of test, developing a pronounced curve with last few chambers, ventral sutures slightly sigmoid; wall coarsely perforate on both sides; aperture on the periphery, at the base of the last chamber, extending on to the dorsal side along the spiral suture for one or two chambers, with a narrow lip.

This species exhibits some variation as to

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EXPLANATION OF PLATE 30

FIG. *1—Bolivina subadvena sulphurensis* Cushman & Adams, ×49. *a*, side view; *b*, apertural view.
*2—Plectofrondicularia advena* (Cushman), ×31. *a*, side view; *b*, apertural view.
*3—Plectofrondicularia californica* Cushman & R. E. Stewart, ×33. *a*, side view; *b*, apertural view.
*4—Bulimina affinis* d'Orbigny, ×38. *a*, side view; *b*, apertural view.
*5—Bulimina denudata deformata* Cushman & Parker, ×63. *a*, side view; *b*, apertural view.
*6—Bulimina pagoda hebespinata* R. E. & K. C. Stewart, ×63. *a*, side view; *b*, apertural view.
*7—Bulimina rostrata* Brady, ×84. *a*, side view; *b*, apertural view.
*8—Bulimina subacuminata* Cushman & R. E. Stewart, ×70. *a*, side view; *b*, apertural view.
*9—Bulimina subcalva* Cushman & K. C. Stewart, ×56. *a*, side view; *b*, apertural view.
*10—Globobulimina pacifica curtata* White, n. var. Holotype, ×61. *a*, side view; *b*, apertural view.
*11—Virgulina nodosa* R. E. & K. C. Stewart, ×51, *a*, side view; *b*, apertural view.
*12—Buliminella curta* Cushman, ×105. *a*, side view; *b*, top view.
*13—Buliminella subfusiformis* Cushman, ×56. Side view.

thickness, the figured specimen being an extremely thickly developed individual with a relatively large umbo. Most of the specimens from this area however, were found to compare favorably with the original illustration of Galloway & Wissler.

*Hypotype.*—USC No. 3509, lower Pliocene.

### Genus PLANULINA d'Orbigny, 1826
### PLANULINA ORNATA (d'Orbigny)
Pl. 28, fig. 7a–c

*Truncatulina ornata* D'ORBIGNY, 1839, Voy. Amer. Merid., vol. 5, Foraminiferes, p. 40, pl. 6, fig. 7,9; Recent, Chile.

*Planulina ornata* CUSHMAN, 1927, Bull. Scripps Inst. Oceanography, Tech. Ser., vol. 1, p. 176, pl. 6, fig. 12; Recent, Eastern Pacific. CUSHMAN, STEWART & STEWART, 1930, Trans. San Diego Soc. Nat. Hist., vol. 6, p. 78, pl. 7, fig. 7a–c; Pliocene, California. CORYELL & MOSSMAN, 1942, Jour. Paleo., vol. 16, p. 237, pl. 36, fig. 2,3; Pliocene, Panama. CUSHMAN & GRAY, 1946, Special Publ. 19, Cushman Lab. Foram. Res., p. 44, pl. 8, fig. 9–12; Pleistocene, California. BANDY, 1953, Jour. Paleo., vol. 27, p. 177, pl. 24, fig. 4; Recent, Pacific.

Test plano-convex, much compressed, dorsal side flat or sometimes slightly concave, previous whorls partially visible on ventral side although usually somewhat obscured by secondary filling of shell material; chambers 8 to 9 in last formed whorl, gradually increasing in size, the last three or four usually slightly inflated; sutures limbate and very strongly curved on both sides almost joining the periphery tangentially; wall very coarsely punctate; aperture on periphery at base of septal face and extending along spiral suture on dorsal side for three chambers with noticeable lip.

*Hypotype.*—USC No. 3526, lower Pliocene.

## Family CHILOSTOMELLIIDAE Brady, 1884
### Genus CHILOSTOMELLA Reuss, 1850
### CHILOSTOMELLA CZIZEKI Reuss
Pl. 29, fig. 2a–c

*Chilostomella czizeki* REUSS, 1850, Denkschr. Acad. Wis. Wien., vol. 1, p. 380, pl. 48, fig. 13; Miocene, Austria. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 126, pl. 20, fig. 7a–c; Pliocene, California. (See this reference for synonomy.)

*Hypotype.*—USC No. 3508, lower Pliocene.

## Family ORBULINIDAE Schultze, 1854
### Genus ORBULINA d'Orbigny, 1839
### ORBULINA UNIVERSA d'Orbigny
Pl. 29, fig. 1

*Orbulina universa* D'ORBIGNY, 1839, De La Sagra, Hist. Phys. Pol. Nat. Cuba. Foraminiferes, p. 2, pl. 1, fig. 1; Recent, type locality not given. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 128, pl. 21, fig. 4; Pliocene, California. (See this reference for synonomy.)

*Hypotype.*—USC No. 3525, lower Pliocene.

## Family HETEROHELICIDAE Cushman, 1927
### Genus BOLIVINA d'Orbigny, 1839
### BOLIVINA ACUMINATA Natland
Pl. 29, fig. 3a–b

*Bolivina subadvena* var. *serrata* NATLAND 1938, (not Chapman, 1892), Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 4, p. 145, pl. 5, fig. 8,9; Recent, Pacific. CUSHMAN & MCCULLOCH, 1942, Allan Hancock Pacific Exped., vol. 6, p. 213, pl. 26, fig. 14; pl. 27, fig. 1,2; Recent, Pacific.

*Bolivina subadvena* var. *acuminata* NATLAND, 1946, in Cushman & Gray, Special Publ. 19, Cushman Lab. Foram. Res., p. 34, pl. 5, fig. 46; Pleistocene (reworked Pliocene and Miocene). California. CUSHMAN, STEWART & STEWART, 1949, Oregon Dept. Geol. and Min. Ind., Bull. 36, p. 153, pl. 17, fig. 10a,b; Pliocene, Washington.

*Bolivina acuminata* NATLAND, 1950, Geol. Soc. Amer., Memoir 43, pt. 4, p. 22, pl. 5, fig. 21a,b; Pliocene, Carmen Island. BANDY, 1953, Jour. Paleo., vol. 27, p. 176, pl. 24, fig. 6; Recent, Pacific.

Test medium sized, elongate, two times as long as wide, rhomboid in cross section, periphery sharp with a serrate keel; initial end broad in megalospheric forms and pointed in microspheric individuals, sides gently tapering from the broadest point just below the last pair of chambers; chambers uniform, gradually increasing in size as added, 9 to 12 pairs in adult specimens; sutures limbate, slightly arched, making an angle of approximately 45 degrees with the periphery; wall smooth with medium sized perforations. Aperture a slit on the septal face of last chamber.

*Hypotype.*—USC No. 3482, lower Pliocene.

### BOLIVINA ARGENTEA Cushman
Pl. 29, fig. 4a,b

*Bolivina argentea* CUSHMAN, 1926, Contr. Cushman Lab. Foram. Res., vol. 2, p. 42, pl. 6, fig.

5; Pliocene, California. NATLAND, 1950, Geol. Soc. Amer., Memoir 43, pt. 4, p. 20, pl. 5, fig. 13a,b; Pliocene, Carmen Island. CROUCH, 1952, Bull. Amer. Assoc. Petrol. Geol., vol. 36, p. 828, pl. 3, fig. 1; Recent, Pacific. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 128, pl. 21, fig. 5a,b, 6a,b; Pliocene, California. (See this reference for synonomy.)

*Hypotype.*—USC No. 3483, lower Pliocene.

### BOLIVINA BRAMLETTEI Kleinpell
Pl. 29, fig. 5a,b, 6

*Bolivina beyrichi* var. *alata* RANKIN, 1931, *in* Hoots [not *Bolivina alata* Sequenza, 1862] U. S. Geol. Survey, Prof. Paper 165-C, p. 113; upper Miocene.

*Bolivina bramlettei* KLEINPELL, 1938, Miocene Stratigraphy of California, p. 267, pl. 21, fig. 9–11; upper Miocene, California.

Test medium sized, elongate, compressed, about two times as long as wide, periphery acute with a narrow keel, developing a spine at the peripheral end of each chamber; initial end blunt, rapidly increasing in size until greatest width reached about half way up the test; chambers uniform, gradually increasing in size, 7 to 8 pairs in adult individual; sutures narrow, depressed, steeply arched forming a shallow reentrant at base of each chamber, and meeting the periphery tangentially; wall smooth with medium to coarse perforations; aperture a narrow slit on septal face of last chamber.

*Hypotype.*—USC No. 3484, upper Miocene.

### BOLIVINA DECURTATA Cushman
Pl. 29, fig. 7a,b

*Bolivina decurtata* CUSHMAN, 1926, Contr. Cushman Lab. Foram. Res., vol. 2, p. 44, pl. 6, fig. 7a,b. CUSHMAN, 1937, Special Publ. 9, Cushman Lab. Foram. Res., p. 118, pl. 14, fig. 10; Pliocene, California. KLEINPELL, 1938, Miocene Stratigraphy of California, p. 270, pl. 21, fig. 3,8; Miocene, California.

Test elongate, compressed, about 2 times as long as wide, periphery narrow but rounded, sides tapering inward gradually toward initial end from the widest point of test approximately 2 chambers below aperture; chambers 8 or 9 pairs, gradually increasing in size and height as added, not inflated; sutures highly curved toward center of test, becoming straightened near periphery, arched upward, making an angle of 50 to 55 degrees with the periphery; wall smooth, with medium sized perforations; aperture a narrow slit at base of septal face of last chamber.

*Hypotype.*—USC No. 3486, upper Miocene.

### BOLIVINA FORAMINATA R. E. & K. C. Stewart
Pl. 29, fig. 8a,b

*Bolivina seminuda* var. *foraminata*. R. E. & K. C. STEWART, 1930, Jour. Paleo., vol. 4, p. 66, pl. 8, fig. 5a,b; Pliocene, California. CUSHMAN, 1937, Special Publ. 9, Cushman Lab. Foram. Res., p. 119, pl. 14, fig. 11; Pliocene, California. KLEINPELL, 1938, Miocene Stratigraphy of California, p. 281; upper Miocene, California.

*Bolivina foraminata* CORYELL & MOSSMAN, 1942, Jour. Paleo., vol. 16, p. 239, pl. 36, fig. 34; Pliocene, Panama.

Test elongate, slightly twisted, 2 times as long as wide, initial end narrow, but gradually increasing in size with the addition of each pair of chambers; periphery broadly rounded, slightly lobulate; chambers slightly inflated, 8–9 pairs, nearly twice as wide as high, sutures strongly curved in center of test, becoming straight, and making an angle of nearly 90 degrees with the periphery; wall smooth with medium perforations, upper portion of all but the early chambers free of pores; aperture a narrow slit on the lower part of the septal face of last chamber.

*Hypotype.*—USC No. 3488, upper Miocene.

### BOLIVINA POCHEENSIS White, n. sp.
Pl. 29, fig. 13a,b

Test small, 2½ times as long as wide, somewhat compressed in cross section, initial end narrow, but gradually increasing in size as chambers are added; periphery rounded, chambers very slightly inflated, with 8–10 pairs; sutures slightly curved, with a downward arch, meeting the periphery at approximately an 80 degree angle; wall smooth, with fine to medium perforations, the upper portion of the last few chambers always free of pores and with the early portion of the test exhibiting this feature in some individuals; aperture a narrow slit on the septal face of last chamber. Length,

0.33 mm.; width, 0.14 mm.; thickness, 0.09 mm.

*Holotype.*—USC 3569, upper Miocene. USC Locality 150.

### Bolivina seminuda humilis Cushman & McCulloch
Pl. 29, fig. 9a,b, 10a,b

*Bolivina seminuda* Cushman, 1937 (part), Special Publ. 9, Cushman Lab. Foram. Res., p. 142, pl. 18, fig. 14–15 (not 13); Recent, Pacific.

*Bolivina seminuda* var. *humilis* Cushman & McCulloch, 1942, Allan Hancock Pacific Exped., vol. 6, p. 211, pl. 26, fig. 1–6; Recent, Pacific.

Test elongate, about 2½ times as long as wide, greatest width reached about ⅔ of the distance from the initial end, gradually tapering from small proloculum, oval in cross section; chambers closely appressed, very slightly inflated near apertural end, 1½ to 2 times wider than high, 8 to 10 pairs; sutures curved, arching downward; wall smooth with medium perforations, upper ¼ of chambers clear, with no pores; aperture a narrow slit on septal face of last chamber.

*Hypotype.*—USC No. 3489, upper Miocene.

### Bolivina semiperforata Martin
Pl. 29, fig. 11a,b

*Bolivina semiperforata* Martin, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 129, pl. 21, fig. 10a,b, 11a,b; Pliocene, California.

*Hypotype.*—USC No. 3490, lower Pliocene.

### Bolivina sinuata Galloway & Wissler
Pl. 29, fig. 12a,b

*Bolivina sinuata* Galloway & Wissler, 1927, Jour. Paleo., vol. 1, p. 71, pl. 11, fig. 9a,b; Pleistocene, California. Cushman, 1937, Special Publ. 9, Cushman Lab. Foram. Res., p. 120, pl. 14, fig. 19,20; Pliocene, California. Martin, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 129 pl. 22, fig. 1a,b; Pliocene, California.

*Hypotype.*—USC No. 3491, upper Miocene; also occurs in lower Pliocene.

### Bolivina subadvena sulphurensis Cushman & Adams
Pl. 30, fig. 1a,b

*Bolivina subadvena* var. *sulphurensis* Cushman & Adams, 1935, Contr. Cushman Lab. Foram. Res., vol. 11, p. 20, pl. 3, fig. 8,9; Pliocene, California. Cushman, 1937, Special Publ. 9, Cushman Lab. Foram. Res., p. 117, pl. 12, fig. 19,20; late Tertiary, California. Martin, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 130, pl. 22, fig. 4a,b, 5a,b; Pliocene, California.

*Hypotype.*—USC No. 3493, lower Pliocene.

## Genus Plectofrondicularia Liebus, 1903

### Plectofrondicularia advena (Cushman)
Pl. 30, fig. 2a,b

*Frondicularia inaequalis* H. B. Brady, 1884 (*not* Costa), Rep. Voy. Challenger, Zool., vol. 9, p. 521, pl. 66, fig. 8–12; Recent, Atlantic, Pacific.

*Frondicularia advena* Cushman, 1923, U. S. Nat. Mus. Bull. 104, p. 141, pl. 20, fig. 1, 2; Recent, Atlantic. Galloway & Wissler, 1927, Jour. Paleo., vol. 1, p. 47, pl. 8, fig. 7,8; Pleistocene, California. Cushman, Stewart & Stewart, 1930, Trans. San Diego Soc. Nat. Hist., vol. 6, p. 57, pl. 3, fig. 5; Pliocene, California. Cushman & Gray, 1946, Special Publ. 19, Cushman Lab. Foram. Res., p. 15, pl. 3, fig. 16; Pleistocene, California. Martin, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 117, pl. 17, fig. 2a,b; Pliocene, California.

Test elongate, highly flattened, tapering gradually from wide apertural end to narrow initial end, periphery thin but rounded, chambers strongly equatant, added biserially in early portion, soon becoming uniserial, 10 or more in the mature forms; sutures slightly depressed; wall smooth, finely perforate; aperture terminal, a small oval opening surrounded by very low rim.

Miss Ruth Todd examined the holotype and paratype of *Frondicularia advena* in addition to a number of other specimens on file at the U.S.N.M. in Washington D.C., and was unable to distinguish any radiate markings around the aperture. The definite biserial character of the early portion (mentioned as "coiled in part" in the original description) and the absence of a radiate aperture, indicate the inclusion of this form in the genus *Plectrofrondicularia* rather than *Frondicularia*.

*Hypotype.*—USC No. 3527, lower Pliocene.

### Plectofrondicularia californica Cushman & R. E. Stewart
Pl. 30, fig. 3a,b

*Plectofrondicularia californica* Cushman & R. E. Stewart, 1926, Contr. Cushman Lab. Foram. Res., vol. 2, p. 39, pl. 6, fig. 9–11; Pliocene, California. Cushman, Stewart & Stewart,

1947, Oregon Dept. Geol. Min. Ind., Bull. 36, p. 16, pl. 2, fig. 2a,b; Miocene, Oregon. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 130, pl. 22, fig. 6a,b, 7a,b; Pliocene, California. (See this reference for synonomy.)

*Hypotype.*—USC No. 3528, lower Pliocene.

Family BULIMINIDAE Jones, 1876
Genus BULIMINA d'Orbigny, 1826
BULIMINA AFFINIS d'Orbigny
Pl. 30, fig. 4a,b

*Bulimina affinis* D'ORBIGNY, 1840, *in* Sagra, Historia fisica, politica y natural de la isla de Cuba, Foraminiferes, vol. 6, p. 109, pl. 2, fig. 25,26; Recent, Cuba. CUSHMAN, 1922, U. S. Nat. Mus. Bull. 104, p. 103, pl. 20, fig. 6; Recent, Atlantic. CUSHMAN & PARKER, 1940, Contr. Cushman Lab. Foram. Res., vol. 16, p. 7, pl. 2, fig. 1–4; Recent, Cuba. CROUCH, 1952, Bull. Amer. Assoc. Petrol. Geol., vol. 36, p. 826, pl. 1, fig. 15; Recent, Pacific. BANDY, 1953, Jour. Paleo., vol. 27, p. 176, pl. 24, fig. 9; Recent, Pacific.

Test large, subround in cross section, about 1½ times as long as the diameter, increasing very rapidly in size from the blunt initial end to the widest portion just below the mid-point; chambers about 3 per whorl, elongate, inflated, later chambers embracing the upper half of test; sutures slightly depressed; wall smooth with medium perforations; aperture subterminal, a loop-shaped opening with large protruding tooth, on the inner face of last chamber.

*Hypotype.*—USC No. 3494, lower Pliocene.

BULIMINA DENUDATA
DEFORMATA Cushman & Parker
Pl. 30, fig. 5a,b

*Bulimina pagoda* CUSHMAN, STEWART & STEWART, 1930 (*not* Cushman), Trans. San Diego Soc. Nat. Hist., vol. 6, p. 66, pl. 5, fig. 6a–c; Pliocene, California.

*Bulimina pagoda* var. *deformata* CUSHMAN & PARKER, 1938, Contr. Cushman Lab. Foram. Res., vol. 14, p. 58, pl. 10, fig. 3a–c; Pliocene, California.

*Bulimina denudata* var. *deformata* CUSHMAN & PARKER, 1947, U. S. Geol. Survey, Prof. Paper 210-D, p. 118, pl. 27, fig. 15.

*Bulimina marginata* NATLAND, 1950, (*not* d'Orbigny), Geol. Soc. Amer., Memoir 43, pt, 4, p. 17, pl. 5, fig. 5a,b; Pliocene, Carmen Island.

Test elongate, subround in cross section, about 1½ to 2 times as long as wide, tapering gradually from wide apertural end to near pointed initial end, periphery highly irregular due to the extreme undercutting of the chambers toward the sutures; chambers 3 per whorl with approximately 6 whorls forming a mature specimen, except in the very early portion every chamber undercut, and all chambers having a series of short spines along the projecting edges; sutures depressed; wall smooth, very finely perforate; aperture a comma-shaped opening in a slight depression on the inner face of the last chamber.

*Hypotype.*—USC No. 3495, lower Pliocene.

BULIMINA PAGODA HEBESPINATA
R. E. & K. C. Stewart
Pl. 30, fig. 6a,b

*Bulimina pagoda* var. *hebespinata* R. E. & K. C. STEWART, 1930, Jour. Paleo., vol. 4, p. 63, pl. 8, fig. 3a,b; Pliocene, California. CUSHMAN & PARKER, 1938, Contr. Cushman Lab. Foram. Res., vol. 14, p. 55, pl. 9, fig. 6,7; Pliocene, California. CUSHMAN & PARKER, 1947, U. S. Geol. Survey, Prof. Paper 210-D, p. 117, pl. 27, fig. 9,10; Pliocene, California. CUSHMAN, STEWART & STEWART, 1949, Oregon Dept. Geol. and Min. Ind., Bull. 36, p. 152, pl. 17, fig. 11; Pliocene, Washington.

Test elongate, about 2 times as long as wide, gradually increasing in size from sharp initial end to maximum thickness at next to last whorl; chambers inflated, 3 per whorl, globular, sharply undercut, with several well developed spines arranged in a row around the midpoint; in the early portion of the test these spines dominate the chambers; wall with medium perforations; aperture a comma shaped opening on the inner face of the last chamber.

This form was compared with the holotype by Miss Ruth Todd and was found to fall within the range of that variety.

*Hypotype.*—USC No. 3496, upper Miocene.

BULIMINA ROSTRATA Brady
Pl. 30, fig. 7a,b

*Bulimina rostrata* H. B. BRADY, 1884, Rep. Voy. Challenger, Zool., vol. 9, p. 408, pl. 51, fig. 14,15; Recent. CUSHMAN, 1911, U. S. Nat. Mus. Bull. 71, p. 87, text-fig. 140a,b; Recent, North Pacific. CUSHMAN, 1927, Scripps Inst. Oceanography Bull. Tech. Ser., vol. 1, p. 152, pl. 2, fig. 12; Recent, Pacific. CUSHMAN, 1942, U. S. Nat. Mus. Bull. 161, p. 10, pl. 3, fig. 12; Recent, Pacific. CUSHMAN & PARKER, 1947, U. S. Geol.

Survey Prof. Paper 210-D, p. 124, pl. 28, fig. 34; Recent, Atlantic and Pacific; Pliocene, California. BANDY, 1953, Jour. Paleo., vol. 27, p. 176, pl. 24, fig. 12; Recent, Pacific.

Test small for genus, elongate, about twice as long as wide, subtriangular in cross section; chambers 3 per whorl, about 8 whorls forming a mature test; chambers highly appressed somewhat rectangular in shape, gradually increasing in size as added; sutures slightly depressed, difficult to discern; wall finely perforate, with 10 or 11 high plate-like longitudinal costae which are continuous across the sutures; aperture a comma-shaped opening in a slight depression on the inner face of last chamber.

There has been some confusion between this species and *Bulimina fossa* Cushman & Parker. It is distinguished from *B. fossa* by its more fusiform shape, and in the more plate-like development of the longitudinal costae.

*Hypotype.*—USC No. 3497, lower Pliocene.

BULIMINA SUBACUMINATA
Cushman & R. E. Stewart
Pl. 30, fig. 8a,b

*Bulimina subacuminata* CUSHMAN & R. E. STEWART, 1930, Trans. San Diego Soc. Nat. Hist., vol. 6, p. 65, pl. 5, fig. 2, 3a,b; Pliocene, California. CROUCH, 1952, Bull. Amer. Assoc. Petrol. Geol., vol. 36, pl. 2, fig. 7; Recent, Pacific. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 132, pl. 22, fig. 12a,b; Pliocene, California. (See this reference for synonomy.)

*Hypotype.*—USC No. 3498, lower Pliocene.

BULIMINA SUBCALVA Cushman &
K. C. Stewart
Pl. 30, fig. 9a,b

*Bulimina subcalva* CUSHMAN & K. C. STEWART, 1930, Trans. San Diego Soc. Nat. Hist., vol. 6, p. 65, pl. 4, fig. 8a–c; Pliocene, California. CUSHMAN & PARKER, 1938, Contr. Cushman Lab. Foram. Res., vol. 14, p. 55, pl. 9, fig. 8a–c; Pliocene, California. CUSHMAN & PARKER, 1946, U. S. Geol. Survey Prof. Paper 210-D, p. 116, pl. 27, fig. 7; Pliocene, California. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 132, pl. 22, fig. 13a,b; Pliocene, California.

*Hypotype.*—USC No. 3499, lower Pliocene.

Genus GLOBOBULIMINA Cushman, 1927
GLOBOBULIMINA PACIFICA CURTATA
White, n. var.
Pl. 30, fig. 10a,b

Test small, $1\frac{1}{4}$ times as long as wide, tapering inward from the wide apical end to the roundly pointed apertural end. Chambers elongate, inflated, 3 per whorl, with the last two embracing almost the entire test; sutures narrow, slightly depressed; wall smooth, finely perforate. Aperture a loop-shaped opening with a simple tooth, located at the upper end of the septal face. Length, 0.31 mm., width, 0.27 mm.

This variety differs from *Globobulimina pacifica* Cushman in its shorter length and greater relative width.

*Holotype.*—USC No. 3517, lower Pliocene. USC Locality 147.

Genus VIRGULINA d'Orbigny, 1826
VIRGULINA NODOSA R. E. &
K. C. Stewart
Pl. 30, fig. 11a,b

*Virgulina nodosa* R. E. & K. C. STEWART, 1930, Jour. Paleo., vol. 4, p. 64, pl. 8, fig. 4a–c; Pliocene, California. CROUCH, 1952, Bull. Amer. Assoc. Petrol. Geol., vol. 36, p. 828, pl. 2, fig. 14; Recent, Pacific. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 133, pl. 24, fig. 1a–c; Pliocene, California. (See this reference for synonomy.)

*Hypotype.*—USC No. 3544, lower Pliocene.

Genus BULIMINELLA Cushman, 1911
BULIMINELLA CURTA Cushman
Pl. 30, fig. 12a,b

*Buliminella curta* CUSHMAN, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, p. 33, pl. 5, fig. 13; Miocene, California. CUSHMAN & LAIMING 1931, (part), Jour. Paleo., vol. 5, p. 106, pl. 11, fig. 16 (not 15); Miocene California. KLEINPELL, 1938, Miocene, Stratigraphy of California, p. 248, pl. 7, fig. 3; pl. 15, fig. 4; pl. 16, fig. 8; Miocene, California. CUSHMAN & PARKER, 1947, U. S. Geol. Survey Prof. Paper 210-D, p. 64, pl. 16, fig. 22; Miocene, California, Alabama, Florida; Pliocene, Italy; Recent, Pacific. CUSHMAN & MCCULLOCH, 1948, Allan Hancock Pacific Exped., vol. 6, p. 235, pl. 29, fig. 1; Recent, Pacific.

Test elongate, about twice as long as wide, nearly circular in cross section, periphery slightly lobulate; chambers 6 to 7 per whorl, slightly inflated, early chambers nearly square, becoming higher than wide

in later stages of growth; sutures depressed, somewhat curved; wall smooth, finely perforate; aperture a comma-shaped opening in a wide depression on the septal face of the last chamber.

*Hypotype.*—USC No. 3500, upper Miocene; also occurs in lower Pliocene.

BULIMINELLA SUBFUSIFORMIS Cushman
Pl. 30, fig. 13

*Buliminella subfusiformis* CUSHMAN, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, p. 33, pl. 5, fig. 12; Miocene, California. CUSHMAN, Stewart & Stewart, 1947, Oregon Dept. Geol. Min. Ind., Bull. 36, p. 17, pl. 2, fig. 7a,b; Miocene, Oregon. NATLAND, 1950, Geol. Soc. Amer., Memoir 43, pt. 4, p. 17, pl. 5, fig. 5a,b; Pliocene, Carmen Island. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 134, pl. 23, fig. 6a,b; Pliocene California. (See this reference for synonomy.)

*Hypotype.*—USC No. 3501, lower Pliocene; also occurs in upper Miocene.

Family CASSIDULINIDAE d'Orbigny, 1839
Genus CASSIDULINA d'Orbigny, 1826
CASSIDULINA CALIFORNICA
Cushman & Hughes
Pl. 31, fig. 1a,b

*Cassidulina californica* CUSHMAN & HUGHES, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, p. 12, pl. 2, fig. 1; Pliocene, California. GALLOWAY & WISSLER, 1927, Jour. Paleo., vol. 1, p. 78, pl. 12, fig. 6,7; Pleistocene, California. CUSHMAN, STEWART & STEWART, 1930, Trans. San Diego Soc. Nat. Hist., vol. 6, p. 75, pl. 6, fig. 8a,b; Pliocene, California. CORYELL & MOSSMAN, 1942, Jour. Paleo., vol. 16, p. 243, pl. 36, fig. 47; Pliocene, Panama. CUSHMAN & GRAY, 1946, Special Publ. 9, Cushman Lab. Foram. Res., p. 39, pl. 7, fig. 10a–c; Pleistocene (reworked Pliocene and Miocene), California. CUSHMAN, STEWART & STEWART, 1949, Oregon Dept. Geol. and Min. Ind., Bull. 36, p. 154, pl. 18, fig. 3; Pliocene, Washington. CROUCH, 1952, Bull. Amer. Assoc. Petrol. Geol., vol. 36, p. 836, pl. 6, fig. 6; Recent, Pacific. BANDY, 1953, Jour. Paleo., vol. 27, p. 176, pl. 25, fig. 1; Recent, Pacific.

Test subcircular in side view, sides parallel in end view, periphery broadly rounded; chambers 4 to 4½ pairs in last whorl, with only small portion of the second chamber of any pair visible from the side, very slightly inflated, sutures slightly depressed and limbate, nearly radial; walls smooth, with medium perforations; aperture a narrow slit in the septal face of the last chamber, parallel to the plane of coiling.

Specimens from the Capistrano formation are smaller than those originally described but seem to be similar in all other respects and are thus placed in this species.

*Hypotype.*—USC No. 3502, lower Pliocene.

CASSIDULINA CUSHMANI
R. E. & K. C. Stewart
Pl. 31, fig. 2a,b

*Cassidulina cushmani* R. E. & K. C. STEWART, 1930, Jour. Paleo., vol. 4, p. 71, pl. 9, fig. 5a,b; Pliocene, California. CORYELL & MOSSMAN, 1942, Jour. Paleo., vol. 16, p. 243, pl. 36, fig. 48; Pliocene, Panama. NATLAND, 1950, Geol. Soc. Amer., Memoir 43, pt. 4, p. 34, pl. 9, fig. 9a,b; Pliocene, Carmen Island. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 135, pl. 24, fig. 5a,b; Pliocene, California.

Test small, subcircular in side view, end view roughly lenticular; periphery sharp with a very slight keel on some specimens, slightly lobulate; chambers 4 pairs in last whorl, increasing in size rapidly, somewhat inflated; sutures depressed, curved, especially so in last part of whorl; wall smooth, finely perforate; aperture a narrow slit parallel to the plane of coiling, on the inner face of the last chamber.

There has been much confusion in the past between *Cassidulina cushmani* and *C. delicata* Cushman. These two forms are very similar and possibly may be the same or varieties of a single species. Individuals encountered in both the Miocene and Pliocene samples appear more like *C. cushmani*.

*Hypotype.*—USC No. 3503, upper Miocene; also lower Pliocene.

CASSIDULINA LAEVIGATA
CARINATA Silvestri
Pl. 31, fig. 3a,b

*Cassidulina laevigata* var. *carinata* SILVESTRI, 1896, Acad. Pont. Nuovi Lincei, Mem., vol. 12, p. 104, pl. 2, fig. 10a–c; lower Pliocene, Italy. CUSHMAN, STEWART & STEWART, 1947, Oregon Dept. Geol. Min. Ind., Bull. 36, p. 21, pl. 3, fig. 7a–c; Miocene, Oregon.

*Cassidulina corbyi* MARTIN, 1952, (*not* Cushman & Hughes). Contr. Cushman Found. Foram. Res., vol. 3, p. 135, pl. 24, fig. 3a,b; Pliocene, California.

Test small, subcircular in side view, somewhat compressed, periphery lobulate, sharp, with a narrow keel which in some specimens is poorly defined; chambers about 5 pairs in

last whorl; sutures distinct, slightly depressed, in early portion nearly straight, becoming increasingly curved with last two chambers; wall smooth, finely perforate; aperture an elongate slit on septal face of last chamber, parallel to the plane of coiling.

These specimens seem to be intermediate between forms belonging to *Cassidulina laevigata* and *C. laevigata carinata*. The presence of a keel, even though poorly developed, on most of the individuals suggests that they be assigned to the variety.

*Hypotype.*—USC No. 3504, lower Pliocene.

CASSIDULINA LOMITENSIS
Galloway & Wissler
Pl. 31, fig. 4a,b

*Cassidulina lomitensis* GALLOWAY & WISSLER, 1927, Jour. Paleo., vol. 1, p. 79, pl. 12, fig. 10a,b; Pleistocene, California. CROUCH, 1952, Bull. Amer. Assoc. Petrol. Geol., vol. 36, p. 838, pl. 6, fig. 10; Recent, Pacific. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 135, pl. 24, fig. 7a,b; Pliocene, California. (See this reference for synonomy.) BANDY, 1953, Jour. Paleo., vol. 27, p. 176, pl. 25, fig. 5; Recent, Pacific.

*Hypotype.*—USC No. 3505, lower Pliocene.

CASSIDULINA TRANSLUSCENS
Cushman & Hughes
Pl. 31, fig. 5a,b

*Cassidulina transluscens* CUSHMAN & HUGHES, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, p. 15, pl. 2, fig. 5; Pleistocene, California. CROUCH, 1952, Bull. Amer. Assoc. Petrol. Geol., vol. 36, p. 838, pl. 6, fig. 13; Recent, Pacific. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 136, pl. 24, fig. 4a,b; Pliocene, California. (See this reference for synonomy.) BANDY, 1953, Jour. Paleo., vol. 27, p. 176, pl. 25, fig. 6; Recent, Pacific.

*Hypotype.*—USC No. 3506, lower Pliocene.

Genus CASSIDULINOIDES Cushman, 1927
CASSIDULINOIDES CORNUTA (Cushman)
Pl. 31, fig. 6a–c

*Virgulina cornuta* CUSHMAN, 1913, Proc. U. S. Nat. Mus., vol. 44, p. 637, pl. 80, fig. 1; Recent, Philippines. CUSHMAN & MOYER, 1930, Contr. Cushman Lab. Foram. Res., vol. 6, p. 57, pl. 8, fig. 1; Recent, California coast. CUSHMAN, 1937, Special Publ. 9, Cushman Lab. Foram. Res., p. 28, pl. 4, fig. 20,21; Recent, California. CROUCH, 1952, Bull. Amer. Assoc. Petrol. Geol., vol. 36, p. 828, pl. 2, fig. 13; Recent, Pacific. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 133, pl. 23, fig. 9a–c; Pliocene, California.

Test elongate, 1½ times as long as broad, tapering rapidly from narrow rounded initial end to point of greatest width at approximately midpoint of test; chambers arranged biserially, compressed, about 4 pairs added in a twisted fashion; last 2 chambers becoming very large and embracing most of the test on the apertural side; sutures slightly depressed, curved on apertural side; wall smooth, finely perforate; aperture elongate, comma-shaped, extending obliquely across the septal face of the last chamber.

*Hypotype.*—USC No. 3507, lower Pliocene.

Genus EHRENBERGINA Reuss, 1850
EHRENBERGINA COMPRESSA Cushman
Pl. 31, fig. 8a–c

*Ehrenbergina compressa* CUSHMAN, 1927, Scripps Inst. Oceanography Bull., Tech. Ser., vol. 1,

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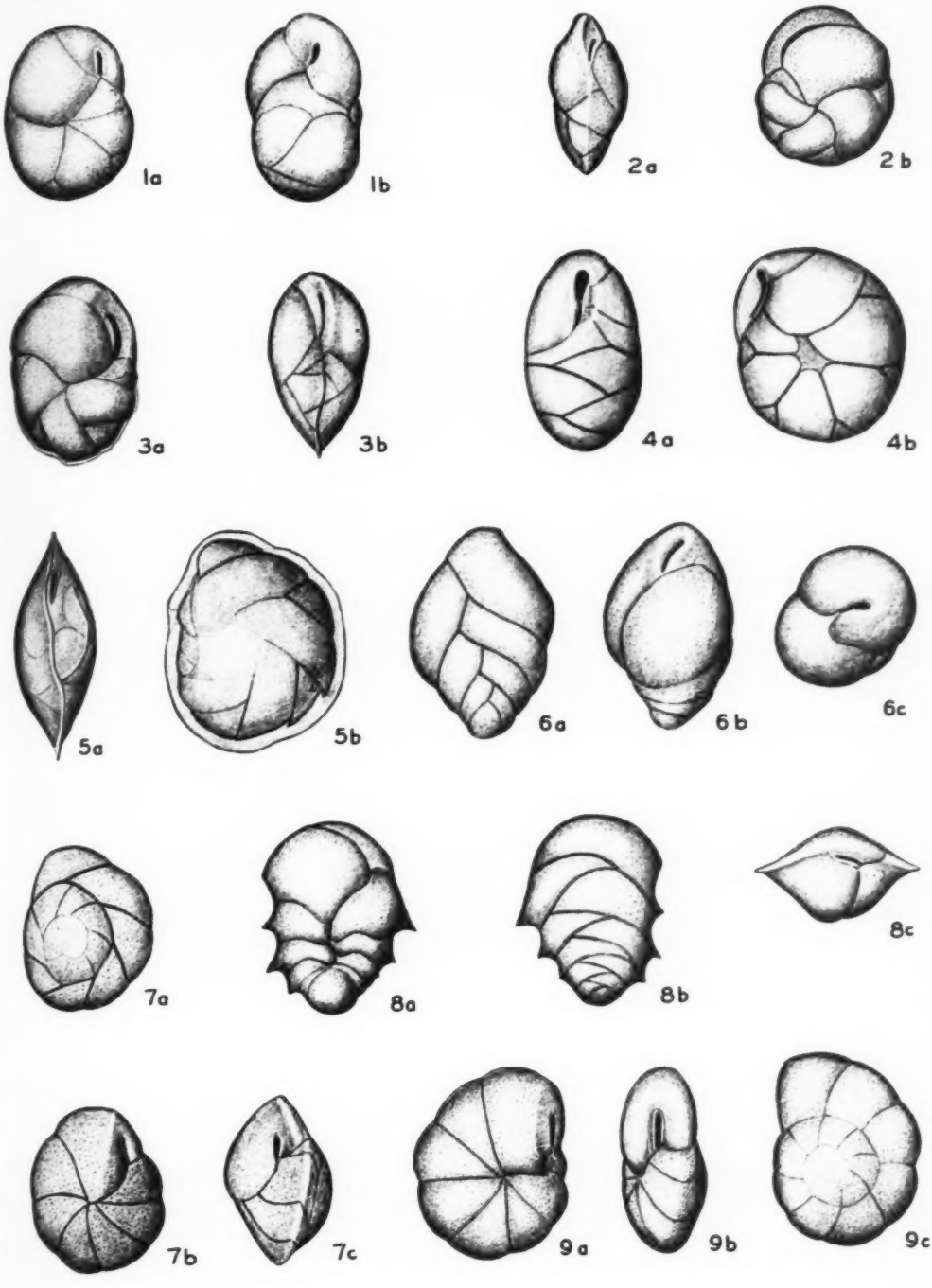
EXPLANATION OF PLATE 31

FIG. *1*—*Cassidulina californica* Cushman & Hughes, ×80. *a*, side view; *b*, edge view.
*2*—*Cassidulina cushmani* R. E. & K. C. Stewart, ×100. *a*, edge view; *b*, side view.
*3*—*Cassidulina laevigata carinata* Silvestri, ×76. *a*, side view; *b*, edge view.
*4*—*Cassidulina lomitensis* Galloway & Wissler, ×42. *a*, edge view; *b*, side view.
*5*—*Cassidulina transluscens* Cushman & Hughes, ×56. *a*, edge view; *b*, side view.
*6*—*Cassidulinoides cornuta* (Cushman), ×70. *a*, back view; *b*, side view; *c*, top view.
*7*—*Epistominella bradyana* (Cushman), ×80. *a*, dorsal view; *b*, ventral view; *c*, edge view.
*8*—*Ehrenbergina compressa* Cushman, ×70. *a*, front view; *b*, back view, *c*, apertural view.
*9*—*Epistominella pontoni californica* White, n. var. Holotype, ×120. *a*, ventral view; *b*, edge view; *c*, dorsal view.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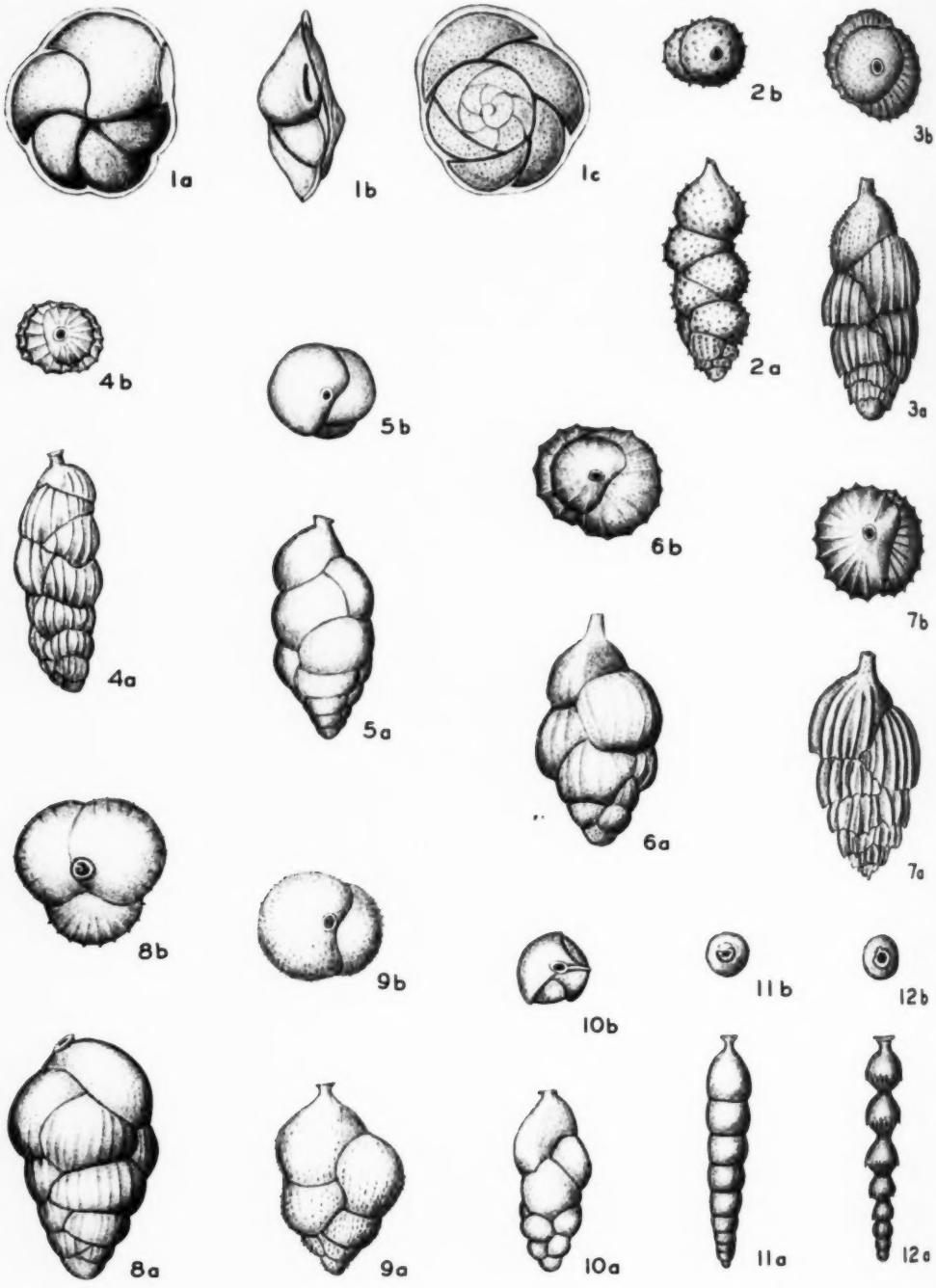
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p. 168, pl. 6, fig. 7; Recent, Pacific. CUSHMAN, STEWART & STEWART, 1930. Trans. San Diego Soc. Nat. Hist., vol. 6, p. 75, pl. 6, fig. 9; Pliocene, California. NATLAND, 1950, Geol. Soc. Amer., Memoir 43, pt. 4, p. 35, pl. 9, fig. 11a–c; Pliocene, Carmen Island. CROUCH, 1952, Bull. Amer. Assoc. Petrol. Geol., vol. 36, p. 841, pl. 6, fig. 19; Recent, Pacific.

Test short, about 1½ times as long as wide, periphery sharp, and spinose, early portion tending to coil but soon becoming evolute; chambers about 5 pairs, each chamber widely overlapping the preceding one on the inner side, outer edge of each chamber tends to develop a short spine; sutures depressed on inner side, smooth on outer; wall smooth with medium perforations; aperture a narrow slit in upper face of last chamber, parallel to direction of elongation of the chambers.

*Hypotype.*—USC No. 3510, lower Pliocene.

### Genus EPISTOMINELLA Husezima & Maruhasi, 1944

#### EPISTOMINELLA BRADYANA (Cushman)

Pl. 31, fig. 7a–c

*Truncatulina pygmaea* BRADY, 1884, (part) (*not* Hantken), Rep. Voy. Challenger, Zool., vol. 9, p. 666, pl. 95, fig. 10; Recent, Atlantic, Pacific.
*Pulvinulinella bradyana* NATLAND, 1950, Geol. Soc. Amer., Memoir 43, pt. 4, p. 33, pl. 9, fig. 3; Pliocene, Carmen Island.
*Epistominella bradyana* MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 136, pl. 24, fig. 9a–c; Pliocene, California. (See this reference for synonomy.)

The figured specimen is more convex and thus has a greater width than is average for the species. Most of the specimens encountered were thinner and appeared to be typical of the species.

*Hypotype.*—USC No. 3511, lower Pliocene.

#### EPISTOMINELLA PONTONI CALIFORNICA White, n. var.

Pl. 31, fig. 9a–c

Test small, subcircular in side view, periphery rounded, slightly biconvex, but sides nearly parallel, dorsal side higher than ventral which is somewhat depressed in the umbilical area; 2½ whorls visible on the dorsal side; chambers 7 to 9 in last whorl, uniform throughout, gradually increasing in size as added; dorsal sutures oblique, very slightly limbate, ventral sutures nearly radial; wall smooth, very finely perforate; aperture a narrow opening on the septal face of the last chamber, and elongate in the plane of coiling. Diameter, 0.19 mm.; thickness, 0.10 mm.

The variety is distinguished by the less limbate ventral sutures, the somewhat more rounded periphery, and the nearly parallel sides.

*Holotype.*—USC No. 3512, upper Miocene. USC Locality 150.

#### EPISTOMINELLA SMITHI (R. E. & K. C. Stewart)

Pl. 32, fig. 1a–c

*Pulvinulinella smithi* R. E. & K. C. STEWART, 1930, Jour. Paleo., vol. 4, p. 70, pl. 9, fig. 4a–c; Pliocene, California.

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### EXPLANATION OF PLATE 32

FIG. 1—*Epistominella smithi* (R. E. & K. C. Stewart), ×76. *a*, ventral view; *b*, edge view; *c*, dorsal view.
2—*Uvigerina hispida* Schwager, ×51. *a*, side view; *b*, apertural view.
3—*Uvigerina hispidocostata* Cushman & Todd, ×45. *a*, side view; *b*, apertural view.
4—*Uvigerina hollicki* Thalmann, ×45. *a*, side view; *b*, apertural view.
5—*Uvigerina hootsi* Rankin, ×38. *a*, side view; *b*, apertural view.
6—*Uvigerina kernensis subcalva* White, n. var. Holotype, ×63. *a*, side view; *b*, apertural view.
7—*Uvigerina peregrina* Cushman, ×56. *a*, side view; *b*, apertural view.
8—*Uvigerina segundoensis* Cushman & Galliher, ×45. *a*, side view; *b*, apertural view.
9—*Uvigerina senticosa adiposa* White, n. var. Holotype. ×86. *a*, side view; *b*, apertural view.
10—*Angulogerina hughesi* (Galloway & Wissler), ×76. *a*, side view; *b*, apertural view.
11—*Siphonodosaria advena* (Cushman & Laiming), ×30. *a*, side view; *b*, apertural view.
12—*Siphonodosaria lepidula* (Schwager), ×31. *a*, side view; *b*, apertural view.

*Pulvinulinella smithi* CUSHMAN & PARKER, 1931, Contr. Cushman Lab. Foram., Res., vol. 7, p. 14, pl. 2, fig. 12a–c; Miocene, California.
*Pseudoparrella smithi* CROUCH, 1952, Bull. Amer. Assoc. Petrol. Geol., vol. 36, p. 836, pl. 6, fig. 2,3; Recent, Pacific.
*Epistominella smithi* BANDY, 1953, Jour. Paleo., vol. 27, p. 177, pl. 23, fig. 7; Recent, Pacific.

Test unequally biconvex, dorsal side nearly flat, subcircular in side view, periphery sharp, keeled, moderately lobulate, about 3 whorls visible on dorsal side; chambers 5 to 6 in last coil, increasing gradually in size in first 2 whorls and expanding rapidly in last whorl; early chambers nearly rhomboid later becoming crescent shaped; dorsal sutures somewhat limbate, with the radial sutures slightly curved, but strongly angled opposite to the direction of coiling; ventral sutures depressed and strongly curved; wall smooth, finely perforate; aperture a slit on the septal face of last chamber, parallel to the plane of coiling.

*Hypotype.*—USC No. 3513, lower Pliocene; also occurs in upper Miocene.

## Family UVIGERINIDAE Galloway & Wissler, 1927

## Genus UVIGERINA d'Orbigny, 1826

### UVIGERINA HISPIDA Schwager

Pl. 32, fig. 2a,b

*Uvigerina hispida* SCHWAGER, 1866, Novara Exped., Geol. Theil., Bd. 2, Abt. 2, p. 249, pl. 7, fig. 95; Pliocene, India. CUSHMAN & TODD, 1941, Contr. Cushman Lab. Foram. Res., vol. 17, p. 73, pl. 17, fig. 8; Pliocene, India. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 136, pl. 25, figs. 1a,b; Pliocene, California.

Test elongate, 3 times as long as wide, sides nearly parallel, periphery lobulate; chambers inflated, compressed, usually 3 to a whorl, with last 1 or 2 whorls sometimes only containing 2; wall ornamented with short spines which are usually not aligned; aperture round, terminal, at the end of a relatively long neck, with no phialine lip.

The figured specimen is rather atypical in that it becomes biserial in the last 3 whorls. Most of the individuals encountered have 3 chambers per whorl up to the last coil.

*Hypotype.*—USC No. 3535, lower Pliocene.

### UVIGERINA HISPIDOCOSTATA Cushman & Todd

Pl. 32, fig. 3a,b

*Uvigerina hispido-costata* CUSHMAN & TODD, 1945, Special Publ. 15, Cushman Lab. Foram. Res., p. 51, pl. 7, fig. 27,31; Miocene, Jamaica. BERMUDEZ, 1949, Special Publ. 25, Cushman Lab. Foram. Res., p. 206, pl. 13, fig. 37,38; upper Miocene, Dominican Republic. MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 136, pl. 25, fig. 2a,b; Pliocene, California.

*Hypotype.*—USC No. 3536, lower Pliocene.

### UVIGERINA HOLLICKI Thalmann

Pl. 32, fig. 4a,b

*Uvigerina peregrina* var. *bradyana* CUSHMAN, 1923, (*not U. bradyana* Fornasini, 1900) U. S. Nat. Mus. Bull. 104, p. 168, pl. 42, fig. 12; Recent, Atlantic. CUSHMAN, 1927, Scripps Inst. Oceanography Bull., Tech. Ser., vol. 1, p. 158, pl. 4, fig. 2; Recent, Pacific. CUSHMAN, STEWART & STEWART, 1930, Trans. San Diego Soc. Nat. Hist., vol. 6, p. 69, pl. 5, fig. 12; Pliocene, California. CUSHMAN, 1936, Bull. Geol. Soc. Amer., vol. 47, p. 429, pl. 5, fig. 10. CUSHMAN & MCCULLOCH, 1948, Allan Hancock Pacific Exped., vol. 6, p. 266, pl. 34, fig. 1; Recent, California coast.
*Uvigerina hollicki* THALMANN, 1950, Contr. Cushman Found. Foram. Res., vol. 1, p. 45. BANDY, 1953; Jour. Paleo., vol. 27, p. 177, pl. 25, fig. 8; Recent, Pacific.

Test elongate, about 3 times longer than the diameter, periphery lobulate, sides nearly parallel, about 6 whorls in mature forms; chambers 3 per whorl, inflated, closely appressed in early portion; sutures depressed; wall finely perforate, ornamented with high plate-like costae, 8 to 9 per chamber, not continuous across the sutures; aperture terminal, at the end of a short neck with a slight phialine lip.

*Hypotype.*—USC No. 3537, lower Pliocene.

### UVIGERINA HOOTSI Rankin

Pl. 32, fig. 5a,b

*Uvigerina hootsi* RANKIN, 1934, *in* CUSHMAN & KLEINPELL. Contr. Cushman Lab. Foram. Res., vol. 10, p. 22, pl. 3, fig. 8,9; Miocene, California. KLEINPELL, 1938, Miocene Stratigraphy of California, p. 295, pl. 22, fig. 6; Miocene, California. CUSHMAN, 1941, Contr. Cushman Lab. Foram. Res., vol. 17, p. 46, pl. 13, fig. 16,17; Miocene, California. CUSHMAN & GRAY, 1946, Special Publ. 19, Cushman Lab. Foram. Res., p. 36, pl. 6, fig. 13; Pleistocene,

California (reworked Miocene and Pliocene). CUSHMAN & MCCULLOCH, 1948, Allan Hancock Pacific Exped., vol. 6, p. 229, pl. 33, fig. 3; Recent (?), Miocene (?), Eastern Pacific.

Test elongate, nearly 4 times as long as wide, rapidly increasing in size in early portion, sides later tending to become nearly parallel; 5 to 7 whorls in adult forms; chambers 3 per whorl, very closely appressed in early part, becoming larger and more globular towards the apertural ends; sutures depressed, becoming deeper away from the initial end; wall finely perforate, always smooth in later portion, but some tests show a number of very fine longitudinal costae on the lower half; aperture terminal, central, subround at end of a short neck with a distinct phialine lip.

*Hypotype.*—USC No. 3538, upper Miocene.

### UVIGERINA KERNENSIS SUBCALVA White, n. var.

Pl. 32, fig. 6a,b

*Uvigerina kernensis?* CUSHMAN & MCCULLOCH, 1948, (*not* Barbat & von Estorff), Allan Hancock Pacific Exped., vol. 6, p. 261, pl. 33, fig. 5; Recent, California coast.

Test elongate, about 2 times as long as wide, nearly fusiform with greatest width reached at next to the last whorl; chambers inflated, closely appressed, especially in the early portion, 3 per whorl with about 4 whorls comprising the mature specimens; sutures depressed, wall finely perforate with low longitudinal costae which are broken at the sutures; aperture terminal at the end of a long neck, with a slight phialine lip developed on some individuals. Length, 0.5 mm.; diameter, 0.25 mm.

Variety differing from the typical in the lack of minute spines on the last chambers, and in the much longer apertural neck.

*Holotype.*—USC No. 3539, lower Pliocene. USC Locality 146.

### UVIGERINA PEREGRINA Cushman

Pl. 32, fig. 7a,b

*Uvigerina pigmea* FLINT, 1899, (*not* d'Orbigny), Rep. U. S. Nat. Mus., p. 320, pl. 68, fig. 2; Recent, Western Atlantic.

*Uvigerina peregrina* MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 137, pl. 25, fig. 7a,b; Pliocene, California. (See this reference for a more complete synonomy.) BANDY, 1953, Jour. Paleo., vol. 27, p. 177, pl. 25, fig. 10; Recent, Pacific.

*Hypotype.*—USC No. 3540, lower Pliocene.

### UVIGERINA SEGUNDOENSIS Cushman & Galliher

Pl. 32, fig. 8a,b

*Uvigerina segundoensis* CUSHMAN & GALLIHER, 1934, Contr. Cushman Lab. Foram. Res., vol. 10, p. 26, pl. 4, fig. 11; Miocene, California. KLEINPELL, 1938, Miocene Stratigraphy of California, p. 297; Miocene, California. CUSHMAN & TODD, 1941, Contr. Cushman Lab. Foram. Res., vol. 17, p. 51, pl. 14, fig. 18; Miocene, California. CUSHMAN & MCCULLOCH, 1948, Allan Hancock Pacific Exped., vol. 6, p. 269, pl. 34, fig. 6; Recent, Pacific.

Test elongate, about 1½ times as long as wide, tapering gradually and evenly from the broad apertural end to the narrow initial end; chambers inflated, closely appressed in early portion, becoming globular in the later portion of test, 3 per whorl with from 5 to 6 whorls in the mature specimens; sutures depressed; wall finely perforate, with low, longitudinal costae, 9 to 10 per chamber and not continuous across the sutures; aperture terminal, central, at end of a short neck with a slight lip and characterized by a narrow rod-like tooth on one side.

*Hypotype.*—USC No. 3541, upper Miocene.

### UVIGERINA SENTICOSA ADIPOSA White, n. var.

Pl. 32, fig. 9a,b

Test small, short, about 1½ times as long as wide, periphery lobulate, about 4 whorls, early portion definitely triserial tending to become biserial in last whorl; chambers inflated, closely appressed in early portion, becoming globular in later part; sutures depressed; wall finely perforate, ornamented with small papillae, some arranged in longitudinal rows; aperture terminal at end of a relatively long thin neck with a small phialine lip. Length, 0.29 mm.; diameter, 0.18 mm.

Variety differs in having a less coarsely spinose ornamentation and in its shorter length, the rapid increase in size toward the apertural end, and the more globose nature of the test.

*Holotype.*—USC No. 3542, lower Pliocene. USC Locality 148.

Genus ANGULOGERINA Cushman, 1927

ANGULOGERINA HUGHESI
(Galloway & Wissler)
Pl. 32, fig. 10a,b

*Uvigerina hughesi* GALLOWAY & WISSLER, 1927, Jour. Paleo., vol. 1, p. 76, pl. 12, fig. 5; Pleistocene, California.

*Angulogerina hughesi* CUSHMAN, STEWART & STEWART, 1930, Trans. San Diego Soc. Nat. Hist., vol. 6, p. 70, pl. 5, fig. 16; Pliocene, California. CUSHMAN & TODD, 1941, Contr. Cushman Lab. Foram. Res., vol. 17, p. 76, pl. 18, fig. 4; pl. 19, fig. 17; Pliocene, California. CUSHMAN & TODD, 1947, Special Publ. 21, Cushman Lab. Foram. Res., p. 19, pl. 3, fig. 8; Recent, off coast of Washington. CUSHMAN & MCCULLOCH, 1948, Allan Hancock Pacific Exped., vol. 6, p. 289, pl. 36, fig. 2; Recent, Pacific.

Test relatively small, elongate, about 3½ times as long as wide, periphery lobulate, sides nearly parallel; chambers inflated, globular, gradually increasing in size as added, 3 per whorl with about 3 to 4 whorls in mature specimens; last chamber extremely angular, having a triangular cross section; wall finely perforate, smooth; aperture terminal, elliptical, at the end of a broad short neck with a small phialine lip.

*Hypotype.*—USC No. 3481, lower Pliocene.

Genus SIPHONODOSARIA Silvestri, 1924

SIPHONODOSARIA ADVENA
(Cushman & Laiming)
Pl. 32, fig. 11a,b

*Nodogenerina advena* CUSHMAN & LAIMING, 1931, Jour. Paleo., vol. 5, p. 106, pl. 11, fig. 19; Miocene, California. NATLAND, 1950, Geol. Soc. Amer., Memoir 43, pt. 4, p. 17, pl. 5, fig. 4a,b; Pliocene, Carmen Island.

*Siphonodosaria advena* MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 138, pl. 25, fig. 10a,b; Pliocene, California. (See this reference for synonomy.)

*Hypotype.*—USC No. 3532, lower Pliocene.

SIPHONODOSARIA LEPIDULA (Schwager)
Pl. 32, fig. 12a,b

*Nodosaria lepidula* SCHWAGER, 1886, Novara Exped., Geol. Theil., p. 210, pl. 5, fig. 27,28; Pliocene, India. NATLAND, 1950, Geol. Soc. Amer., Memoir 43, pt. 4, p. 16, pl. 5, fig. 3a,b; Pliocene, Carmen Island.

*Siphonodosaria lepidula* MARTIN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, p. 139, pl. 25, fig. 12a,b; Pliocene, California. (See this reference for synonomy.)

*Hypotype.*—USC No. 3533, lower Pliocene.

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JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 2, P. 261–273, PL. 33, 34, 1 TEXT-FIG., MARCH 1956

# CONODONTS FROM THE MIDDLE DEVONIAN BONE BEDS OF CENTRAL AND WEST-CENTRAL OHIO

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ABSTRACT—Conodonts referable to 7 identifiable species distributed among 10 conodont genera, are reported from bone bed accumulations in the Middle Devonian Columbus and Delaware limestones of central and west-central Ohio. The collection, believed to be the oldest heretofore described systematically from the North American Devonian, is dominated by representatives of the platform-type genera, *Icriodus* and *Polygnathus;* however, fragmentary specimens of 7 bar- and blade-type genera are also described. *Bryantodus solidus*, *Icriodus angustus*, and *Prioniodina arlingtonensis*, are described as new species.

WHILE he was associated with the Ohio State University, Dr. John W. Wells (1944a) initiated an exhaustive investigation of the bone beds which have long been known to occur in the Middle Devonian limestones of central and west-central Ohio. In his report, Wells discusses the ecological significance of fish remains found in these unusual layers, and calls attention to the presence in the same units of arenaceous foraminifers, ostracodes, scolecodonts, sponge spicules, lycopod spore exines, and conodonts. The fish remains were described systematically by Wells (1944b), the foraminiferal assemblage by Stewart and Lampe in 1947, and the ostracodes by Stewart in 1950. The present report is, then, the fourth in a series devoted to a description of the microfauna of the Ohio bone beds.

## STRATIGRAPHY AND SIGNIFICANCE OF THE OHIO BONE BEDS

The Middle Devonian limestones of central and west-central Ohio consist of two formations: the Columbus limestone of late Ulsterian age, and the Delaware limestone of early Erian age. These rocks crop out within a belt some 10 miles wide, which trends northward from Pickaway County in south-central Ohio to Erie and Ottawa counties in the north-central portion of the state. Similar strata are also known to be exposed on Kelleys Island in Lake Erie, and comparable limestones occur in the so-called Bellefontaine outlier of east-central Logan County. The latter exposure is separated by about 25 miles from the principal areas of Devonian outcrop, and although somewhat different from those of central Ohio, the Bellefontaine limestones are generally thought to represent the upper portion of the Columbus formation.

The Columbus and Delaware formations contain several thin, more or less continuous zones of sandy, crinoidal limestone, termed "bone beds," in which the fragmentary scales, teeth, plates, and denticles of fish are abundant, and from which representatives of numerous other fossil groups are also known. Two thin bone beds occur in the upper portion of the Columbus formation; one at the very top, and another 9½ feet below the top. A third such unit is recognized in the upper third of the Delaware limestone, and a fourth occurs just above it in some portions of Delaware County. These bone beds have been numbered from one to four, in order of their decreasing age. A thin layer of bluish-green dolomitic sandstone, which occurs at the top of the Columbus limestone in the eastern portion of the Bellefontaine outlier in Logan County, is known as the East Liberty bone bed (Wells, 1944a, p. 280). The relationship of this bed to those of central Ohio has not yet been established, but it is probably somewhat younger. Subsequent to the publication of Wells' studies, a block of limestone exhibiting typical bone bed lithology was discovered in an abandoned quarry just west of the town of Bellefontaine. Its original position in the quarry face could not be located precisely, but the stratigraphic position of the quarry itself indicates that

the material could not have been derived from the East Liberty bed, which is presumably somewhat younger.

The first, third, and fourth bone beds are known only from rather local occurrences in Franklin and Delaware counties, whereas the second can be traced more or less continuously for a distance of some 120 miles northward from Columbus. According to Wells (1944a p. 297), the Ohio bone beds had no single, uniform mode of origin, but appear to be the results of (1) lag concentrations of coarse organic and inorganic material; (2) subaqueous accumulations of coarse material transported from areas of lag concentration; or (3) aeolian deposits derived from subaerial exposures of lag concentrates. Consequently, the present organic components of these beds cannot be regarded as representative of a life association. On the contrary, they appear to be a combination of forms characteristic of different environments, swept together after death. The distribution of the bone beds along the flanks of the Cincinnati arch suggests that they are genetically related to that structure. Some appear to be clastic layers deposited above wave base in fluctuating seas marginal to Cincinnatia, whereas others probably represent subaerial lag concentrates formed along the margins of these seas.

### CONODONTS OF THE BONE BEDS

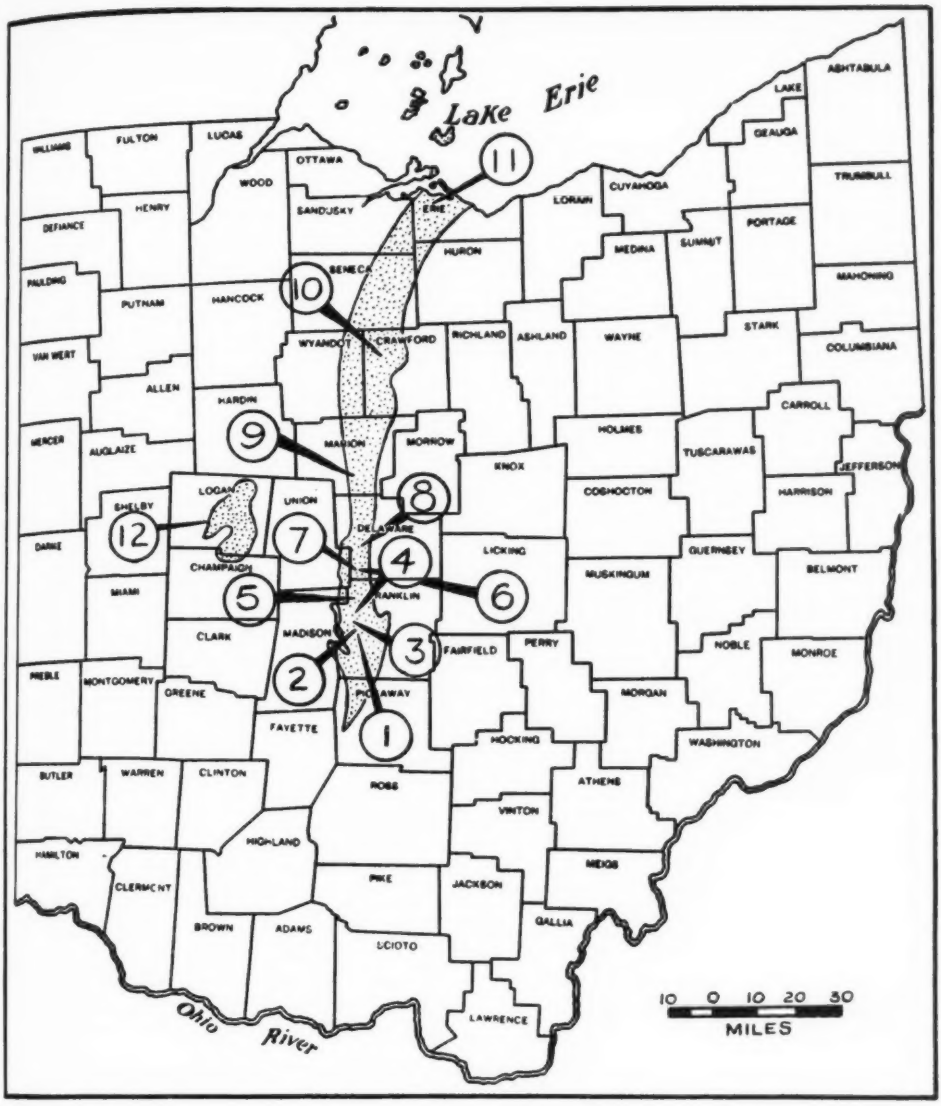
All of the Ohio bone beds, with the exception of the fourth and the East Liberty layer, have yielded conodonts in substantial, if not abundant, quantities; and at least a few identifiable specimens have been recovered from samples collected at each of 12 localities. In addition, a large number of individuals has been obtained from a loose block of bone bed material collected in the western portion of the Bellefontaine outlier. The distribution of bone bed conodont localities is indicated in text-figure 1 and descriptions of these sites are included at the end of our report.

The great majority of the bone bed conodonts show definite evidence of abrasion, a fact which seems to confirm Wells' reconstruction of conditions in the depositional environment. Most of the specimens are pitted; many are frosted. Unbroken representatives of the delicate bar and blade genera are rare in our collections, whereas the more resistant platform types form the bulk of the fauna.

Almost all of the specimens that we are referring to *Polygnathus*, and a considerable number of those belonging in *Icriodus* still retain aborally a portion of the bony material to which they were originally attached. The physical nature of this material is stikingly different from that of the conodont itself. In general, this substance is much softer, opalescent to waxy in luster, and apparently rather porous, for it has been conspicuously stained throughout by secondary iron oxide in most of our specimens.

Professor Duncan McConnell, of the Department of Mineralogy at the Ohio State University, very kindly made petrographic and x-ray diffraction studies of this basal material for us. He reports (letter dated March 11, 1952) that the x-ray powder pattern is " . . . qualitatively identical with the pattern produced by collophane regardless of its source of origin." His petrographic examination further indicated that the material has a "lamellar structural arrangement and appears to be essentially isotropic, which is not characteristic of the conodont material itself." Both of these statements suggest to us that the animal, of which the conodonts were originally a part, had a skeletal (or exoskeletal) framework of lamellar collophane. However, the possibility remains that the basal substance of the conodonts was originally some type of tissue (perhaps cartilagenous) which has been converted to collophane during the process of fossilization.

Altogether, we have collected specimens of 7 identifiable species, referable to 10 conodont genera from the Ohio bone beds. Of these, representatives of *Icriodus* and *Polygnathus* are most abundant. The local occurrence of conodont genera and species now known from the Ohio bone beds is summarized in Table 1. This summary makes it clear that the faunules of the several bone beds are nearly identical, and we have been unable to recognize features in any of these associations which distinguish them from those of other bone bed units. Furthermore, the common forms in




TEXT-FIG. 1—Outline map of Ohio showing outcrop belt of Columbus and Delaware limestones (stippled) and localities from which the bone bed conodonts were collected. Numbers refer to catalogue of localities.

all of the collections are long-ranging types which have a widespread distribution in rocks of Middle and Upper Devonian age. For these reasons, we are not able to make detailed correlations of the Ohio bone beds on the basis of their conodont faunas.

Conodonts have been mentioned (Clarke, 1900) from the Oriskany sandstone of New York, and their presence has been noted (Barnes, Cloud, and Warren, 1945; Hass, 1947) in Lower Devonian limestones in central Texas. However, no genera are cited or faunal elements described in any of these reports. Furthermore, only a few conodonts are known from Middle Devonian rocks, and the majority of these appear

TABLE I.—LOCAL DISTRIBUTION OF OHIO BONE BED CONODONTS

| HORIZON AND LOCALITY (Numbers refer to catalogue of localities) / CONODONT GENERA AND SPECIES | Bone bed 1 | | Bone bed 2 | | | | | | | Bone bed 3 | | | | Bone bed ? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Locality 3 | Locality 6 | Locality 1 | Locality 2 | Locality 3 | Locality 5 | Locality 9 | Locality 10 | Locality 11 | Locality 3 | Locality 4 | Locality 7 | Locality 8 | Locality 12 |
| *Bryantodus solidus* S. & S., n. sp. | | | | | | | | | | X | | | | |
| *Bryantodus* spp. | X | | | | | | X | | X | | | X | | X |
| *Hindeodella* sp. A | | | | | | | | | X | | | | | |
| *Hindeodella* sp. B | | | | | | | | X | | | | | | |
| *Hindeodella?* sp. | | | | | | | X | | X | | | | | X |
| *Icriodus angustus* S. & S., n. sp. | X | | X | | | | | | | X | | X | | X |
| *Icriodus expansus* B. & M. | X | X | X | | | X | X | | X | X | X | | X | X |
| *Icriodus latericrescens* B. & M. | | | | | | X | X | | | | | | | X |
| *Icriodus nodosus*(Huddle) | X | X | | | X | X | X | X | | | X | | | X |
| *Ligonodina* spp. | X | | | | | | | | X | | | | | |
| *Lonchodus?* spp. | | X | X | | | | | | | | | X | | |
| *Ozarkodina* sp. | | | X | | | | | | | | | | | |
| *Polygnathus linguiformis* Hinde | X | X | X | X | | X | X | X | X | X | X | X | X | X |
| *Prioniodina arlingtonensis* S. & S., n. sp. | | | X | | | | | | | | | | | |
| *Prioniodina?* sp. | | | X | | | | | | | | | | | |
| *Prioniodus* sp. | | | | | | | | | | | | X | | |
| *Trichonodella* sp. | | | | | | | | | | | | | | X |

to be somewhat younger than the ones we are studying.

A few conodonts have been reported (Branson and Mehl, 1938; Branson, 1944) from the Mineola limestone of east-central Missouri, and from the Jeffersonville formation of southern Indiana, and Kentucky. All of the specimens known from these formations are apparently referable to *Icriodus*, conspecific forms of which are present in all of the Ohio bone beds. Other elements of the Mineola and Jeffersonville conodont faunas are not known, but their megafossils indicate that only the Jeffersonville should now be correlated with the Columbus limestone of Ohio (Cooper, *et al.*, 1942).

The bone bed collections are reminiscent of the one reported by Downs and Youngquist (1950) from the Cedar Valley limestone of Iowa, but differ significantly from

EXPLANATION OF PLATE 33

FIG. *1,3—Icriodus expansus* Branson & Mehl. Lateral and aboral views of two specimens, ×36. Bone bed 3, Delaware limestone, locality 3. OSU 21009 and 21008.

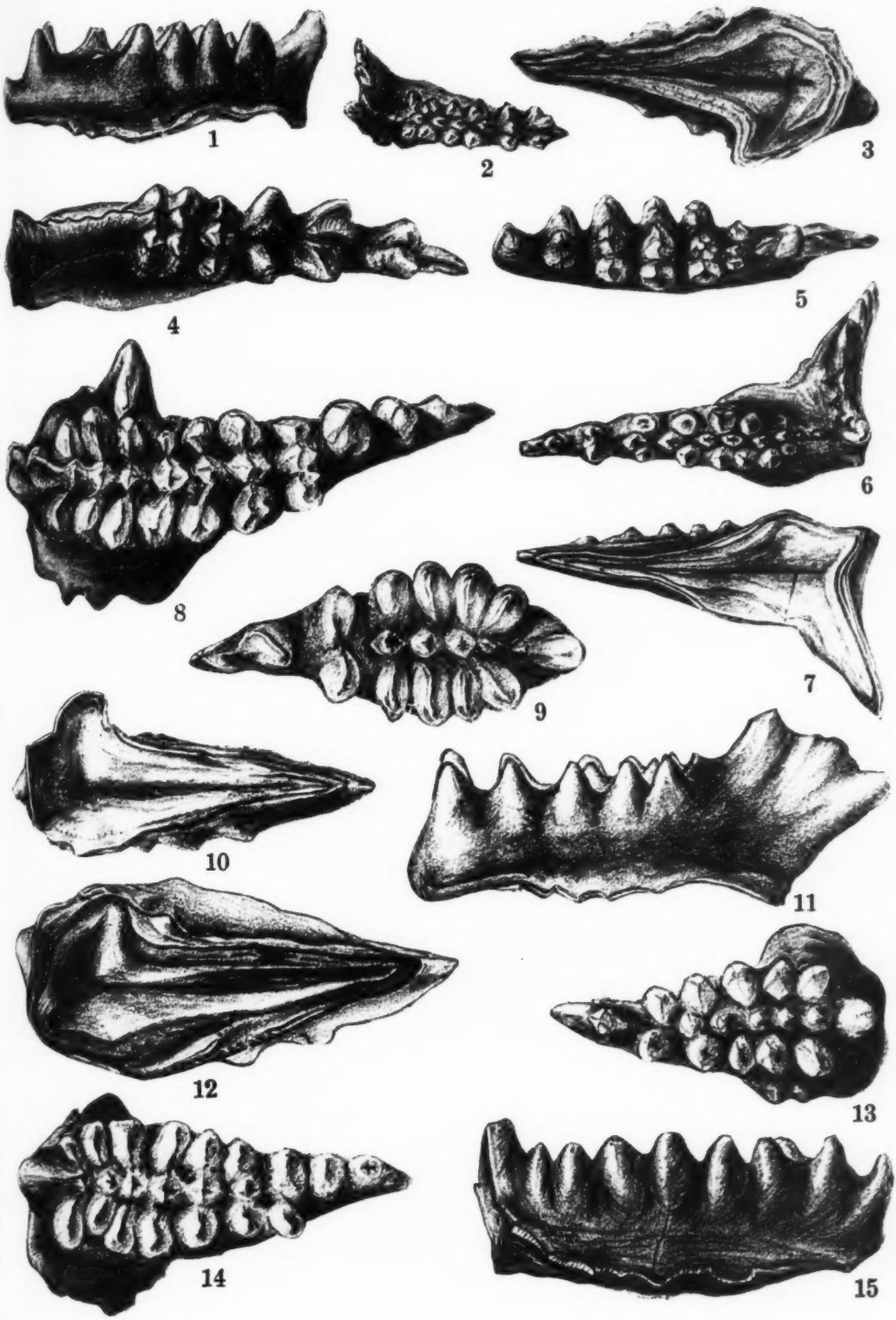
*2—Icriodus latericrescens* Branson & Mehl. Oral view of a small specimen, ×36. Bone bed 2, Columbus limestone, locality 9. OSU 21022.

*4,5,11,15—Icriodus angustus* Stewart & Sweet, n. sp. *4,5,15* are oral and lateral views of the paratypes, *11* is a lateral view of the holotype, ×36. All from bone bed 3, Delaware limestone, locality 3. OSU 20993–20996.

*6,7—Icriodus latericrescens* Branson & Mehl. Oral and aboral views of a single specimen, ×36. Bone bed 2, Columbus limestone, locality 5. OSU 21021.

*8,10—Icriodus nodosus* (Huddle). Oral and aboral views of 2 large specimens, ×36. Bone bed 1, Columbus limestone, locality 3. OSU 21027–21028.

*9,12–14—Icriodus expansus* Branson & Mehl. Oral and aboral views, ×36. Bone beds 1 and 3, Delaware limestone, locality 3. OSU 21004–21007.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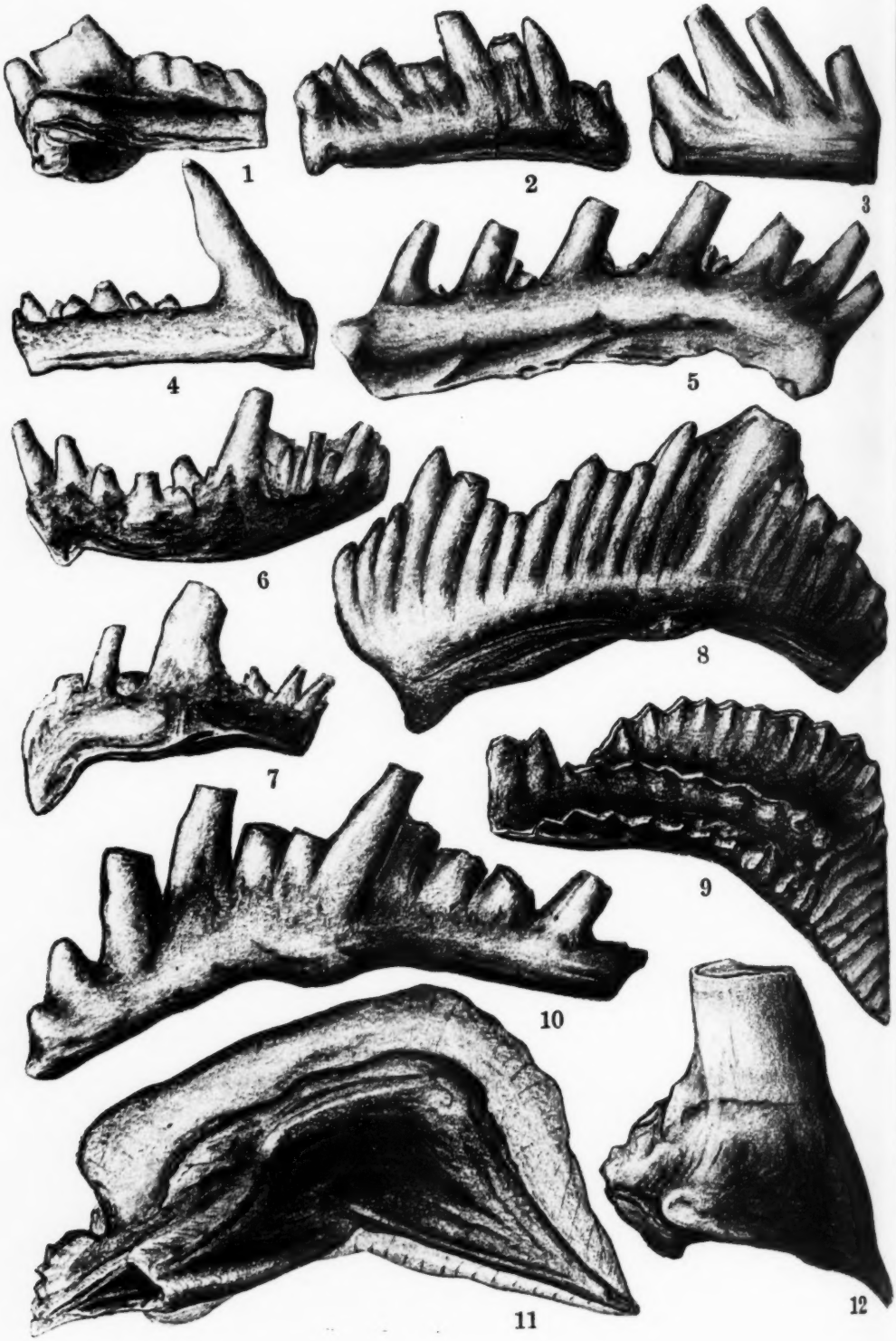
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that described by Stauffer (1940) from the same (?) formation in southern Minnesota. The Iowa collection consists largely of representatives of *Icriodus* and *Polygnathus*, as does the one from the Ohio bone beds; however, *Icriodus* ranges well up into the Upper Devonian, and *Polygnathus* is known from rocks as young as Middle Mississippian in age. Furthermore, the Cedar Valley limestone is generally considered to be somewhat higher in the Middle Devonian than either the Columbus or Delaware formations of Ohio (Cooper, *et al.*, 1942). The presence of *Spathognathodus* [*Pandorina*], and *Synprioniodina* in the Cedar Valley of Minnesota gives its conodont fauna a somewhat younger appearance.

The bone bed conodonts find their closest comparisons in Ohio among those known from the Plum Brook shale (Stauffer, 1938). Furthermore, the Plum Brook conodonts appear to be older than those reported from the typical Olentangy shale, which lies directly above the Delaware limestone in central Ohio. However, this similarity is probably more apparent than real for the components of both conodont faunas belong in long-ranging genera which have little precise stratigraphic significance.

The Columbus limestone has long been correlated with the upper portion of the Onondaga formation of New York, whereas the Delaware is generally equated to some part of the Marcellus. Although we can add nothing to such a correlation from our analysis of the bone bed conodonts, the accepted age assignment indicates that our collections from the Ohio bone beds contain the oldest conodonts heretofore reported systematically from the North American Devonian.

We are indebted to Professor John W. Wells of Cornell University for making portions of his collections available to us for study, and to Professors M. F. Marple and C. H. Summerson of the Ohio State University for calling our attention to a block of conodont-bearing bone bed material in the western portion of the Bellefontaine outlier. The illustrations which accompany our report were made by Mr. Richard A. Wood of Columbus, and were financed by a liberal grant from the Bownocker Fund of the Department of Geology, Ohio State University. All specimens described are on file in the geological museum of the Ohio State University.

## SYSTEMATIC DESCRIPTIONS

### BRYANTODUS SOLIDUS Stewart & Sweet, n. sp.

Pl. 34, fig. 8

Bar moderately arched, strongly bowed, with a promiment median ridge on its inner

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EXPLANATION OF PLATE 34

FIG. 1—*Prioniodina* sp. Lateral view, ×36. Bone bed 2, Columbus limestone, locality 1. OSU 21071.

2—*Ozarkodina* sp. Inner lateral view, ×36. Bone bed 2, Columbus limestone, locality 1. OSU 21045.

3—*Lonchodus?* sp. Lateral view, ×36. Bone bed 2, Columbus limestone, locality 1. OSU 21042.

4—*Ligonodina* sp. Lateral view, ×36. Bone bed 2, Columbus limestone, locality 11. OSU 21039.

5—*Hindeodella* sp. Outer lateral view, ×36. Bone bed 2, Columbus limestone, locality 11. OSU 20987.

6—*Hindeodella* sp. B. Outer lateral view, ×36. Bone bed 2, Columbus limestone, locality 10. OSU 20988.

7—*Hindeodella?* sp. Outer lateral view, ×36. Bone bed 2, Columbus limestone, locality 11. OSU 20990.

8—*Bryantodus solidus* Stewart & Sweet, n. sp. Outer lateral view of the holotype, ×36. Bone bed 3, Delaware limestone, locality 3. OSU 20980.

9,11—*Polygnathus linguiformis* Hinde. Oral and aboral views of 2 nearly complete specimens, ×36. Bone bed 3, Delaware limestone, locality 3. OSU 21046–21047.

10—*Prioniodina arlingtonensis* Stewart & Sweet, n. sp. Lateral view of the holotype, ×36. Bone bed 2, Columbus limestone, locality 1. OSU 21070.

12—*Prioniodus* sp. Lateral view of the anterior portion of a fragmentary specimen, ×36. Bone bed 3, Delaware limestone, locality 7. OSU 21072.

and outer sides. Anterior portion of bar surmounted by 13 laterally compressed, sharply pointed, marginally confluent denticles which are discrete only at their apices. The cusp, which occurs at the apex of the arch, is lenticular in cross section, and strongly inclined to the posterior. The posterior limb of the bar bears at least 6 denticles, which are similar to, although somewhat smaller than those of the anterior wing.

Aborally, the bar tapers to a sharp-edged keel which expands slightly beneath the cusp to form a shallow, subelliptical navel. A marked expansion of the outer lateral bar ridge beneath the cusp forms a prominent rounded knob in the median aboral portion of the outer lateral face.

*Occurrence.*—Bone bed 3, Delaware limestone, locality 3.

*Type.*—Holotype, OSU 20980.

### Bryantodus spp.

Our collections contain a number of fragmentary conodonts which are too poorly preserved to merit illustration, but which are clearly referable to *Bryantodus*. None of these fragments seem close to the holotype of *B. solidus*, which indicates that at least two (and probably more) species of *Bryantodus* are present in the bone beds. We attach no especial significance to these specimens, and mention them only for the sake of completeness.

*Occurrence.*—Bone bed 1, Columbus limestone, locality 3; bone bed 2, Columbus limestone, localities 9 and 11; bone bed 3, Delaware limestone, locality 7; bone bed ?, Columbus limestone, locality 12.

*Repository.*—OSU 20981–20986, inclusive.

### Hindeodella sp. A
Pl. 34, fig. 5

We have two incomplete specimens which clearly belong in *Hindeodella*, but which we are unable to identify specifically. The individual portrayed by figure 5 on Plate 34, represents the posterior portion of a rather long, stout bar which is markedly deflected posteriorly, and slightly bowed laterally. The oral margin is set with a series of 7 long, discrete denticles, which are subcircular in outline and slightly inclined to the posterior. Between each pair of major denticles there is a smaller pair of only slightly erupted denticles whose outlines continue aborally into the base. The bar is laterally expanded orally, but tapers to a rather sharp edge aborally. The posterior end of the bar is laterally compressed, longitudinally spatulate, and abruptly recurved aborally.

*Occurrence.*—Bone bed 2, Columbus limestone, locality 11.

*Repository.*—OSU 20987.

### Hindeodella sp. B
Pl. 34, fig. 6

The specimen represented by figure 6, on Plate 34 consists of the nearly complete anterior end of a rather large individual. The bar is narrow, laterally compressed, slightly bowed, and aborally grooved. Anteriorly, it curves regularly inward to form a distinct lateral process. The bar bears a series of sheathed, laterally confluent oral denticles and a much larger cusp at the junction of the bar and the antero-lateral process. The cusp is subcircular in cross section. The antero-lateral process is set with 5 discrete, sharp-pointed denticles of subequal size and length. The aboral edge of the unit bears a shallow longitiudinal groove which expands beneath the cusp to form a subovate pit, or navel.

*Remarks.*—This specimen differs from the one we are describing as *Hindeodella* sp. A in that the anterior process is not noticeably deflected aborally.

*Occurrence.*—Bone bed 2, Columbus limestone, locality 10.

*Repository.*—OSU 20988.

### Hindeodella? sp.
Pl. 34, fig. 7

Our collections from the second bone bed contain three fragmentary specimens which represent nearly complete anterior ends of a bar-like conodont reminiscent of *Hindeodella*. The cusp is large, posteriorly recurved, and occurs at the junction of the bar and a well developed antero-lateral process. The oral margin of the process is set with five or six small, discrete, slightly recurved denticles, whereas three similar denticles occur on the oral surface of the posterior bar.

The aboral margin is very slightly grooved, the groove expanding into a shallow, thick-lipped navel beneath the

cusp. The antero-lateral process meets the posterior bar at an angle of about 60 degrees, and appears to be only an abrupt anterior recurvature of the bar itself. The process is only slightly deflected aborally.

*Remarks.*—The sheathed relationship of the oral denticles, characteristic of *Hindeodella*, cannot be observed in our specimens. Many hindeodellids can be distinguished from *Ligonodina* only on the basis of the sheathing of the minor denticles, although the anterior process of the latter genus generally has a more marked aboral deflection. Since the antero-lateral process of our specimens is only slightly deflected, we are assigning them provisionally to *Hindeodella*, although such a distinction may be of questionable value.

*Occurrence.*—Bone bed 2, Columbus limestone, localities 9 and 11; bone bed ?, Columbus limestone, locality 12.

*Repository.*—Figured specimen, OSU 20990; unfigured specimens, OSU 20991–20992, inclusive.

### Icriodus angustus Stewart & Sweet, n. sp.
Pl. 33, fig. 4,5,11,15

A number of specimens in our collections appear to be significantly different from any other species heretofore referred to *Icriodus*. We are, therefore, describing them as a distinct species, for which we are proposing the name *Icriodus angustus*.

The oral surface is attenuate, with a sharp pointed anterior terminus and subparallel lateral zones. The denticulated lateral rows diverge slightly near midlength to accommodate a median row of small, discrete nodes. The denticles of all three rows are laterally opposed in the posterior portion of the unit so as to form conspicuous transverse ridges. The denticles of the median row increase in length posteriorly, become contiguous marginally, and form a blunt carina which rises above and extends posterior to the denticles of the marginal rows. In most of our specimens, the denticles of the carina are inclined rather strongly to the posterior.

The attachment scar is deep, narrow, lachrymiform in outline, and only slightly expanded posteriorly. It extends the full length of the aboral side of the unit, and in many specimens is partially filled with bony material.

*Remarks.*—*Icriodus angustus* compares most favorably with *I. rectus* Youngquist & Peterson from the Upper Devonian Sheffield shale of Iowa. It differs from that species, however, in that the posterior, blade-like extension of the median row denticles is more strongly developed, and the unit as a whole is not as expanded laterally. Our specimens are also close to the Grassy Creek individuals described as *I. alternatus* by Branson & Mehl. They differ from the Grassy Creek forms, however, in that the denticles are more prominent, and the nodes of the oral rows do not alternate in position, but form continuous transverse ridges.

*Occurrence.*—Bone bed 1, Columbus limestone, locality 3; bone bed 2, Columbus limestone, locality 1; bone bed 3, Delaware limestone, localities 3 and 7; bone bed ?, Columbus limestone, locality 12.

*Types.*—Holotype, OSU 20993. Figured paratypes, OSU 20994–20996, inclusive; unfigured paratypes, OSU 20997–21003, inclusive.

### Icriodus expansus Branson & Mehl
Pl. 33, fig. 1,3,9,12–14

*Icriodus expansus* Branson & Mehl, 1933 [1934], Missouri Univ. Studies, vol. 8, p. 225. [*Nomen nudum*]. ——Branson & Mehl, 1938, Jour. Paleont., vol. 12, p. 156, 158–161, 164, pl. 26, fig. 18–21. ——Stauffer, 1938, Jour. Paleont., vol. 12, p. 412, 430, pl. 52, fig. 12,14,16,19,20, 25,33,35. ——Stauffer, 1940, Jour. Paleont., vol. 14, p. 425, pl. 60, fig. 40,47,48, 59–64, 70,71. ——Grohskopf, Clark, & Ellison, 1943, Missouri Geol. Surv., 62d Bien. Rep., App. 4, p. 15,16, pl. 2, fig. 1,2,5,8,11,13. ——Branson & Mehl, 1944, *in* Shimer & Shrock, Index fossils of North America, p. 245, pl. 94, fig. 63. ——Mehl & Quigley, 1944, *in* Branson, Missouri Univ. Studies, vol. 19, p. 153, 158, pl. 26, fig. 7–9, 13,14. ——Youngquist & Peterson, 1947, Jour. Paleont., vol. 21, p. 246–247, pl. 37, fig. 5–7,10,20. ——Fay, 1952. Univ. Kansas Paleont. Contr., Vertebrata, Art. 3, p. 110.

Specimens representative of this generalized form of *Icriodus* are numerically conspicuous in our collections from the Ohio bone beds, a relationship that apparently obtains throughout the Middle and Upper Devonian. Individuals typical of the species are characterized by a rather broad oral surface, the lateral margins of which are

conspicuously convex. The anterior terminus of the platform is more sharply pointed than the posterior end, which, in most specimens is rather broadly rounded. The oral surface is surmounted by three longitudinal rows of more or less discrete, anteroposteriorly compressed denticles. The marginal series coverge anteriorly so that near the anterior end of the platform there are only two denticulated rows. At the extreme anterior end of typical specimens, there is only a single denticle. The denticles of the median row are typically less prominent than those of the lateral series throughout most of the platform, but they increase in size and length posteriorly so that the extreme posterior portion of the unit is marked by a large denticle aligned with those of the median row.

The aboral excavation is deeply cupped, lachrymiform in outline, and broadly expanded posteriorly. Most of our specimens retain some whitish or yellowish-brown bony material within the attachment cavity.

*Remarks.*—*Icriodus expansus* is perhaps the simplest of the several species referred to the genus, and probably for that reason it has a reported geologic range coextensive with that of the genus itself. *I. nodosus* (Huddle) is clearly related, differing only in slight lateral elaboration of the attachment cavity to produce a blunt, lobe-like process which is sometimes denticulated orally.

*Occurrence.*—Bone bed 1, Columbus limestone, localities 3 and 6; bone bed 2, Columbus limestone, localities 1, 5, 9, 11; bone bed 3, Delaware limestone, localities 3, 4, 8; bone bed ?, Columbus limestone, locality 12.

*Types.*—Figured plesiotypes, OSU 21004–21009, inclusive. Unfigured plesiotypes, OSU 21010–21020, inclusive.

### Icriodus latericrescens
Branson & Mehl
Pl. 33, fig. 2,6,7

*Icriodus latericrescens* Branson & Mehl, 1938, Jour. Paleont., vol. 12, p. 156, 158, 164, 165, pl. 26, fig. 30–37. ——Stauffer, 1938, Jour. Paleont., vol. 12, p. 413, 430, pl. 52, fig. 30–32,34. ——Branson & Mehl, 1941, Jour. Paleont., vol. 15, p. 100. ——Branson, 1941, Kans. Geol. Soc., Guidebook 15th Ann. Field Conf., p. 83. ——Grohskopf, Clark, & Ellison, 1943, Missouri Geol. Surv., 62d Bien. Rept., App. 4, p. 16, pl. 2, fig. 4,7. ——Branson & Mehl, 1944, *in* Shimer & Shrock, Index fossils of North America, p. 245, pl. 94, fig. 64. ——Branson, 1944, Missouri Univ. Studies, vol. 19, p. 134, 135. ——Youngquist, 1947, Jour. Paleont., vol. 21, p. 102, 103, pl. 25, fig. 12. ——Graves, 1952, Jour. Paleont., vol. 26, p. 612, pl. 81, fig. 9,14–16. ——Fay, 1952, Univ. Kansas Paleont. Contr., Vertebrata, Art. 3, p. 110.

Representatives of this distinctive form are not uncommon in the Ohio bone bed conodont faunas. The platform proper is relatively long and narrow, the sides diverging only slightly throughout their length. Oral denticulation consists of three longitudinal rows of nodular, more or less discrete denticles which converge in such a fashion that only a single row of tubercles is present at the anterior terminus of the unit. The denticles of the median row are somewhat smaller than those of the lateral series, with which they alternate in position, and are typically compressed longitudinally.

Near the posterior end of the platform, the base expands somewhat, and gives rise to a relatively long, sharp pointed lateral process which bears one or more rows of sharp pointed denticles on its oral surface. In most of our specimens, these accessory denticles are less prominent than are those of the platform proper.

The aboral surface of the unit is deeply excavated, the excavation extending nearly to the tip of both the platform and the lateral process. The basal excavation expands from a narrow groove near the distal ends of the limbs to a wide, subquadrate cavity beneath the posterior end of the platform. Several of our specimens retain some bony material within this deep excavation.

*Remarks.*—As pointed out by its authors, *Icriodus latericrescens* is not only the most distinctive of the species commonly referred to the genus, but it is also one of the most variable. However, much of this variation is apparently a result of comparison between individuals representative of different growth stages. Immature specimens, such as the one represented by figure 2 on Plate 33, are generally blunt anteriorly; the addition of the slender anterior terminus of the platform apparently represents a rather late stage in the growth of the individual.

The same general conclusions seem also to apply to differences in length, size, and development of the lateral process.

*Occurrence.*—Bone bed 2, Columbus limestone, localities 5 and 9; bone bed ?, Columbus limestone, locality 12.

*Types.*—Figured plesiotypes, OSU 21021–21022. Unfigured plesiotypes, OSU 21023–21026, inclusive.

### ICRIODUS NODOSUS (Huddle)
Pl. 33, fig. 8,10

*Gondolella? nodosa* HUDDLE, 1934, Bull. Amer. Paleont., vol. 21, no. 72, p. 16, 94, pl. 8, fig. 24,25.

*Icriodus nodosus* BRANSON & MEHL, 1938, Jour. Paleont., vol. 12, p. 156, 158, 159, 160, 163, pl. 26, fig. 14–17,22. ——MEHL & QUIGLEY, and QUIGLEY, respectively, *in* Branson, 1944, Missouri Univ. Studies, vol. 19, p. 153, 158, pl. 26, fig. 6. ——DOWNS & YOUNGQUIST, 1950, Jour. Paleont., vol. 24, p. 670, pl. 87, figs. 17,18,21,22. ——FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, Art. 3, p. 110.

Representatives of this distinctive species are not common in our collections, but several specimens have been recovered from Ohio bone bed material. As others have pointed out (Branson & Mehl, 1938, p. 160; Downs & Youngquist, 1950, p. 670) the species is clearly related to *I. expansus*, differing from it chiefly in that the expanded postero-aboral outline is produced at one side to form a more or less abrupt, subtriangular offset. This offset portion of the basal excavation may or may not bear a small laterally elongate denticle on its oral surface.

The several specimens present in our collections compare favorably with the material illustrated by Branson and Mehl, so we are referring them to *Icriodus nodosus* (Huddle) without question or further description.

*Remarks.*—There are apparently all degrees of gradation between typical *Icriodus expansus* (which has a subcircular postero-aboral outline) and forms thought to be representative of *I. nodosus*. Consequently, it is indeed difficult to recognize meaningful specific limits in this series. Some of the specimens which we are referring to the former species have modified aboral outlines which approach *I. nodosus* in configuration. However, none of these have accessory denticles on the oral surface of the lateral process, a characteristic that we have used to differentiate the two species.

*Occurrence.*—Bone bed 1, Columbus limestone, localities 3 and 6; bone bed 2, Columbus limestone, localities 3, 5, 9, 10; bone bed 3, Delaware limestone, locality 4; bone bed ?, Columbus limestone, locality 12.

*Types.*—Figured plesiotypes, OSU 21027–21028. Unfigured plesiotypes, OSU 21029–21034.

### LIGONODINA spp.
Pl. 34, fig. 4

We are referring to *Ligonodina* four incomplete denticulated bars which are so fragmentary that we are unable to identify them specifically. The individual portrayed by figure 4 on Plate 34 consists of a portion of a bar which is incomplete posteriorly and anteriorly. The oral surface of the bar bears six small denticles, all of which are broken near mid-length and incline slightly to the posterior. The anterior end is set with a large, massive denticle, whose position above a slight expansion of the shallow, groove-like basal excavation indicates that it is the cusp. The bar is strongly bowed laterally, and the general configuration of the broken anterior end suggests that it curved abruptly downward and laterally.

Three additional specimens, which do not merit illustration, appear to represent only the anterior ends of typical ligonodinids. In all of these, there is an abrupt aboro-lateral recurvature of the anterior terminus of the bar, forming a distinct process whose oral margin is set with small, discrete denticles. The aboral surface of each of these specimens is longitudinally grooved, and an elliptical expansion of this groove occurs beneath the junction of the bar and aboro-lateral process.

*Occurrence.*—Bone bed 1, Columbus limestone, locality 3; bone bed 2, Columbus limestone, locality 11.

*Repository.*—Figured specimen, OSU 21039; unfigured specimens, OSU 21040–21041.

### LONCHODUS? spp.
Pl. 34, fig. 3

The specimen illustrated by figure 3 on Plate 34 consists of part of a delicate bar which is subcircular in transverse cross sec-

tion, and bears 4 discrete, posteriorly inclined denticles on its oral surface. The denticles are of subequal size and length, and are uniformly circular in cross section. The aboral edge of the bar is slightly flattened, and in some portions it is slightly excavated longitudinally.

In addition to the individual figured, we have two fragmentary specimens which we are also placing in *Lonchodus* with question. Both of these specimens are incomplete anteriorly and posteriorly, but both have a general physiognomy similar to that of the figured specimen. They differ from it, however, in that the denticles appear to be of alternating size and length.

*Remarks.*—So many fragments of uncertain generic affinities have been referred to Pander's *Lonchodus* that we are no longer certain as to the status of the genus itself. Indeed, Pander himself included in the genus such an apparent variety of incomplete bar-like units that it is difficult to ascertain the proper limits of the group. However, the specimens that we are tentatively referring to *Lonchodus* compare favorably with the accepted type species, *L. simplex* Pander, but they are so incomplete that we cannot make a positive identification.

*Occurrence.*—Bone bed 1, Columbus limestone, locality 6; bone bed 2, Columbus limestone, locality 1; bone bed 3, Delaware limestone, locality 7.

*Repository.*—OSU 21042–21044, inclusive.

### Ozarkodina sp.
Pl. 34, fig. 2

*Ozarkodina* is represented in our collections by the fragmentary anterior portion of a relatively large individual. The blade is laterally compressed, subelliptical in transverse cross section, and surmounted orally by a series of 10 laterally compressed, sharp pointed denticles which are confluent for most of their length above the base. All of the denticles incline slightly to the posterior. The aboral edge of the blade is slightly constricted, thin, and bears a narrow, shallow excavation in its posterior portion. Apparently this excavation expanded rather widely beneath the cusp for that portion of it which is preserved is considerably broader posteriorly than it is anteriorly.

*Occurrence.*—Bone bed 2, Columbus limestone, locality 1.

*Repository.*—OSU 21045.

### Polygnathus linguiformis Hinde
Pl. 34, fig. 9,11

*Polygnathus linguiformis* Hinde, 1879, Geol. Soc. London, Quart. Jour., vol. 35, pt. 3, no. 139, art. 29, p. 367, pl. 17, fig. 15.
*Polygnathus crassus* Hinde, 1879, *idem*, p. 365, pl. 17, fig. 3.
*Polygnathus? simplex* Hinde, 1879, *idem*, p. 367, 368, pl. 17, fig. 18.
*Polygnathus linguiformis* Grabau, 1899, Buffalo Soc. Nat. Sci., Bull., vol. 6, p. 157, fig. 44.
*Polygnathus simplex* Grabau, 1899, *idem*, p. 157, 158, fig. 46.
*Polygnathus linguiformis* Bryant, 1921, Buffalo Soc. Nat. Sci., Bull., vol. 13, p. 25, pl. 11, fig. 1–9. Holmes, 1928, U. S. Nat. Mus., Proc., vol. 72, p. 18, 19, pl. 7, fig. 22.
*Polygnathus simplex* Holmes, 1928, *idem*, p. 18, 19, pl. 7, fig. 5.
*Polygnathus linguiformis* Branson & Mehl, 1933, Univ. Missouri Studies, vol. 8, p. 148, 150, pl. 12, fig. 6,7. [Pages 149 and 150 are reversed in this publication. Page 149 should be p. 150; p. 150 should be p. 149.] ——Huddle, 1934, Bull. Amer. Paleont., vol. 21, no. 72, p. 16, 95, 96, pl. 8, fig. 4,5.
*Polygnathus sanduskiensis* Stauffer, 1938, Jour. Paleont., vol. 12, p. 438, pl. 53, fig. 27,36,37. ——Stauffer, 1940, Jour. Paleont., vol. 14, p. 430, pl. 60, fig. 80,82,89,90.
*Polygnathus linguiformis* Branson, 1944, Missouri Univ. Studies, vol. 19, p. 173.
(?) *Polygnathus sanduskiensis* Thomas, 1949, Geol. Soc. America, Bull., vol. 60, p. 408, pl. 1, fig. 24.
*Polygnathus linguiformis* Fay, 1952, Univ. Kansas Paleont. Contr., Vertebrata, Art. 3, p. 155.
*Polygnathus crassus* Fay, 1952, *idem*, p. 152.
*Polygnathus? simplex* Fay, 1952, *idem*, p. 159.

Specimens in our collections of this common species have a stout, deeply concave platform which is bounded laterally by distinct ridges of fused, laterally compressed denticles. The posterior portion of the platform is produced into a thick, tongue-like process which is deflected aborally, and slightly to markedly twisted laterally. The oral surface of the posterior process bears a series of generally 8 to 10 prominent transverse ridges, although the number of these corrugations is apparently quite variable.

The lateral ridges of the platform proper do not continue onto the oral surface of the posterior process. The ridge on the margin opposite to the direction in which the proc-

ess twists expands adorally near its posterior extremity, and curves slightly inward. The opposed lateral ridge is nearly coincident with the oral plane in its posterior portion, curving slightly orad only near its distal margin. Anteriorly, however, this ridge curves abruptly orad, and is separated from the carina by a deep longitudinal depression.

The carina is thin, blade-like, and composed of 10–15 marginally fused, laterally compressed denticles which are discrete only at their distal ends. This structure extends beyond the platform anteriorly for a distance equivalent to about half the platform length, and is highest and most conspicuous in this portion. Posteriorly, the carina decreases in height, and near the posterior extremity of the platform it is represented by only a few low tubercles or nodes.

The aboral surface is bisected longitudinally by a prominent keel which is deflected laterally beneath the posterior process of the platform. Near platform mid-length, the keel subdivides to form a small, deep, subovate navel or escutcheon; it continues beneath the anterior end of the unit as two parallel, closely approximated ridges. Most of our specimens have a relatively thick, irregular mass of bony material "fused" to the aboral surface.

*Remarks.*—Representatives of this distinct, easily recognizable species are the most common constituents of the bone bed conodont faunas. Our specimens exhibit considerable variation, which is especially noticeable in the length, degree of aboral deflection, and amount of lateral twisting of the posterior platform process. The Genesee specimens from which Hinde selected the holotype appear to represent an extreme, in that the process is long and strongly deflected, whereas some of our specimens have short processes which are only slightly deflected.

Polygnathids from the Widder beds and the Arkona shale of southern Ontario, the Plum Brook and Olentangy shales of Ohio, described by Stauffer as *P. sanduskiensis*, do not appear to differ significantly from the types of *P. linguiformis* Hinde, as refigured by Branson and Mehl in 1933. Our specimens have been carefully compared with topotypes, collected from Hinde's Genesee shale locality, and they are undoubtedly conspecific.

*Occurrence.*—Bone beds 1, 2, and 3, Columbus and Delaware limestones, localities 1–12.

*Types.*—Figured plesiotypes, OSU 21046–21047; unfigured plesiotypes, OSU 21048–21067.

### PRIONIODINA ARLINGTONENSIS Stewart & Sweet, n. sp.
Pl. 34, fig. 10

We have a large specimen from the second bone bed which clearly belongs in the genus *Prioniodina*, but which appears to represent an undescribed species of that genus. The bar and anterior process are of subequal length, the process being deflected aborally at an angle of about 45 degrees, and only slightly curved laterally. The oral surface of both bar and anterior process bears a series of recurved, laterally compressed, discrete denticles, which appear to increase in size and length toward the center of the unit. The aboral margin of the bar and anterior process bears a slight groove-like excavation which flares into a shallow, thick-lipped pit beneath the apical denticle.

*Remarks.*—*Prioniodina arlingtonensis* most closely resembles the prioniodinids described by Branson & Mehl (1934, p. 213–215) from the Grassy Creek shale of Missouri. It differs from those forms, however, in that the denticles are considerably larger, and the bar is not markedly swollen at mid-width.

*Occurrence.*—Bone bed 2, Columbus limestone, locality 1.

*Type.*—Holotype, OSU 21070.

### PRIONIODINA sp.
Pl. 34, fig. 1

Bar laterally expanded, bearing six appressed, slightly inclined denticles (all incomplete) on its oral surface. The preserved portion of the denticle occurring directly above the pit-like expansion of the aboral groove is considerably larger than those adjacent to it, hence it probably represents the cusp. Aboral margin restricted, bearing a narrow, median excavation which expands to form a shallow pit at the anterior end.

*Remarks.*—The general configuration of

the expanded end of this specimen indicates that the anterior process was probably in the same plane as the remainder of the unit, and that the conodont as a whole was but slightly arched. For these reasons we are referring the specimen to *Prioniodina* rather than to *Ligonodina*, which is closely related.

*Occurrence.*—Bone bed 2, Columbus limestone, locality 1.

*Repository.*—OSU 21071.

PRIONIODUS sp.
Pl. 34, fig. 12

Cusp large, asymmetrically lenticular in cross section, being flattened on its inner surface and broadly rounded on its outer face. Anticusp long, thin, aborally pointed, slightly curved to the anterior in its distal portion. Basal excavation shallow, sheathed on the inner side by a broad expansion of the cusp base. Posterior bar missing, but it apparently joined the cusp at an angle somewhat greater than 90 degrees.

*Occurrence.*—Bone bed 3, Delaware limestone, locality 7.

*Repository.*—OSU 21072.

TRICHONODELLA sp.

We have a single, fragmentary specimen from a loose block of bone bed material found near Bellefontaine, Ohio, which is clearly referable to *Trichonodella*, but which is too poorly preserved to merit illustration. We are including a brief discussion of this form, however, largely for the sake of completeness.

Cusp large, subcircular in section, regularly recurved, flanked on either side by a short wing, the oral surfaces of which bear a single, blunt, node-like denticle. Cusp base produced posteriorly to form a short, laterally compressed, nondenticulate bar. Lateral wings and posterior process deeply excavated aborally; a deep, subconical pit with flaring margins occurs beneath the cusp. The entire unit is covered with a druse of minute dolomite (?) crystals, presumably formed during the process of extracting the conodont from its original calcareous matrix.

*Occurrence.*—Bone bed ?, Columbus limestone, locality 12.

*Repository.*—OSU 21073.

CATALOGUE OF LOCALITIES

*Franklin County*

*1.*—Bone bed 2, Columbus limestone. Conodonts secured from a slab of bone bed material in the Ohio State University geological museum, bearing museum number 3818. From one of the now-abandoned quarries near the Marble Cliff Quarry Company office, Arlington, Ohio.

*2.*—Bone bed 2, Columbus limestone. West wall of Hobo quarry (Marble Cliff Quarry Company), on west side of Scioto River opposite Marble Cliff station.

*3.*—Bone beds 1 and 2, Columbus limestone; bone bed 3, Delaware limestone. West wall of Scioto quarry (Marble Cliff Quarry Company), a short distance north of locality 2.

*4.*—Bone bed 3, Delaware limestone. Roadside exposure at the junction of McCoy and Scioto River roads on east side of Scioto River (1 mile north of Fishinger Road bridge).

*5.*—Bone bed 2, Columbus limestone. East wall of J. and L. Snouffer quarry, east side of Scioto River, 1 mile south of Dublin road.

*Delaware County*

*6.*—Bone bed 1, Columbus limestone. Top of section exposed in abandoned (lower) quarry of Miami Stone Company, on west side of Olentangy River, 2 miles north of Bartholomew Run.

*7.*—Bone bed 3, Delaware limestone. Near top of section exposed in southeastern wall of upper Miami Stone Company quarry, 2 miles north of Bartholomew Run.

*8.*—Bone bed 3, Delaware limestone. Top of section exposed in old quarry immediately north of abandoned schoolhouse, west side of Olentangy River, 1 mile north of Stratford, Ohio (Stauffer, 1909, p. 92).

*Marion County*

*9.*—Bone bed 2, Columbus limestone. Upper portion of section exposed in east wall of an abandoned quarry on the north side of road, just east of Owen, Ohio (5 miles southwest of Marion) (Stauffer, 1909, p. 85).

*Crawford County*

*10.*—Bone bed 2, Columbus limestone. Near top of east wall in National Lime and Stone Company quarry, on Broken Sword Creek, 1 mile northwest of Spore, Ohio (6 miles northwest of Bucyrus) (Stauffer, 1909, p. 109).

*Erie County*

*11.*—Bone bed 2, Columbus limestone. Above coral zone in east wall of abandoned quarry at end of railroad spur, 2 miles south of Venice, Ohio (Stauffer, 1909, p. 129).

*Logan County*

12.—Bone bed ?, Columbus limestone. Conodonts obtained from a loose block of bone bed material secured in an abandoned quarry of the Niagara Lime and Stone Company on the west side of Bellefontaine, Ohio.

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# TWO NEW TERTIARY OSTRACODE GENERA FROM FLORIDA*

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ABSTRACT—Two new genera of Ostracoda are described: *Climacoidea* (type species: *C. plueurata* Puri, n. sp.) from the Caloosahatchee marl ("Pliocene") and *Howella* (type species: *Cythere evax* Ulrich and Bassler) from the Miocene of Maryland and Florida. A new species, *Howella echinata*, is described from the Cooper marl (upper Eocene). *Climacoidea* Puri, n. gen., cannot be classified in a family but *Howella* Puri, n. gen., is placed under the subfamily Trachyleberidinae Sylvester-Bradley, 1948.

## INTRODUCTION

THE "form" genus *Cythereis* Jones, 1850, has been a dumping ground for several cytherid genera. Species formerly included in this genus have been transferred to several well-defined genera and most of these genera are now included in the subfamily Trachyleberidinae. In the present paper another cytherid genus is set up to include echinose species which show three well-developed longitudinal rows of spines. Also, a new genus, *Climacoidea*, is proposed for a ribbed species from the Caloosahatchee marl, southern Florida.

## ACKNOWLEDGMENTS

Gratitude is expressed to Dr. H. V. Howe, Director, School of Geology, Louisiana State University, for the Cooper marl sample he furnished and Miss Doryand P. Janson for her assistance in making the illustrations.

## TYPES

Types are deposited in the Florida Geological Survey Museum; the Henry V. Howe collection, Louisiana State University; and the U. S. National Museum, Washington, D.C.

Abbreviations here used for depositories are:

FGS—Florida Geological Survey
HVH—Henry V. Howe collection
USNM—United States National Museum

## LOCALITIES

Listed below are the localities from which samples were collected. Reference to locations contained in the text are indicated by index numbers which precede each entry.

1. Upper Eocene, Cooper marl. Tunnel of city of Charleston, 10 miles north of Charleston, South Carolina. Sample from 50 feet below surface. B. W. Blanpied, collector.
2. Miocene, Choctawhatchee stage, *Ecphora* facies. Jackson Bluff, Ochlockonee River, Leon County, Florida. Sample from top shell bed.
3. Miocene, Choctawhatchee stage, Calvert formation. Plum Point, west side of Chesapeake Bay, cliff 1 mile south of Plum Point, Maryland. Sample from 36 feet above base.
4. "Pliocene," Caloosahatchee marl. LaBelle Chamber of Commerce Picnic Grounds, about two miles southwest of court house, LaBelle, Hendry County, Florida. Sample from the bank of the Caloosahatchee River, three feet above river level.

## Family CYTHERIDAE Baird, 1850
## Subfamily TRACHYLEBERIDINAE Sylvester-Bradley, 1948
## Genus HOWELLA Puri, n. gen.

*Cythere* [part] of authors
*Cythereis* [part] of authors
*Trachyleberis* [part] of authors
*Echinocythereis* Puri, 1954 [part]

Type species: *Cythere evax* Ulrich & Bassler, 1904, p. 119, pl. 36, fig. 6–8.

*Description.*—Carapace subrectangular, subangular posteriorly, subovate in side view. Anterior end broadly rounded, denticulate, with well-developed marginal rim, posterior end subangular to obliquely rounded. Dorsal margin more or less straight, ventral margin concave in the middle. Surface of the carapace in the anterior half ornamented with small, rounded spines arranged concentrically; posterior half with three well-developed rows of echinose spines. Central tubercle well-developed with a cluster of short,

* Publication authorized by the Director, Florida Geological Survey.

stubby spines. Marginal area broad, marginal pore-canals numerous, long and straight, more in the anterior marginal than the posterior and ventral margins. Hinge of right valve with an anterior crenulate tooth with three lobes, a postjacent socket and a posterior knob-like large tooth connected with a groove. Hinge of the left valve complementary.

Named in honor of Dr. Henry V. Howe, Director, School of Geology, Louisiana State University.

*Horizon.*—Miocene.

*Remarks.*—This genus is very close to *Echinocythereis* Puri, 1954, but differs from it in having three well-developed longitudinal rows of spines in the posterior half of the carapace. It differs from *Actinocythereis* Puri, 1952, in being echinose, and having concentrically arranged spines in the anterior half of the carapace. The relationship of *Howella* with *Echinocythereis* is the same as the relationship of *Actinocythereis* with *Trachyleberis* Brady, 1898.

HOWELLA EVAX (Ulrich & Bassler)
Pl. 35, fig. 1–8

*Cythere evax* ULRICH & BASSLER, 1904, Maryland Geol. Survey, Miocene Report, p. 119, pl. 36, fig. 6–8.
*Cythere evax oblongula* (*oblongata* on description of Pl. 36) ULRICH & BASSLER, 1904, Maryland Geol. Survey, Miocene Report, p. 119, pl. 36, fig. 9,10.
*Cythereis evax* SWAIN, 1948, Maryland Dept. Geology, Mines and Water Res., Bull. 2, p. 204, pl. 12, fig. 19,20.
*Trachyleberis evax* SWAIN, 1951, U. S. Geol. Survey, Prof. Paper, 234-A, p. 28, pl. 3, fig. 1–3.
*Echinocythereis evax* PURI, 1954, Florida Geol. Survey, Bull. 36, p. 260, 261, pl. 12, fig. 1; text-fig. 9c.

*Remarks.*—This species was originally described from the Calvert Miocene of Maryland (Ulrich & Bassler, p. 119) and has since been reported from the Florida panhandle (Puri 1954, p. 260, 261). It remains an excellent marker for the Choctawhatchee stage as it is stratigraphically restricted and morphologically very distinct.

Dimensions of plesiotype no. HVH 4700, a right valve from locality no. 2; length .718 mm.; height .425 mm.; plesiotype no. FGS S-5000, a left valve from locality no. 3: length .835 mm.; height .576 mm.

HOWELLA ECHINATA Puri, n. sp.
Pl. 35, fig. 9–14; Pl. 36, fig. 1–4

*Description.*—Carapace large, subrectangular subovate in side view. Anterior end broadly rounded, denticulate; posterior end broadly rounded in the ventral half, obliquely rounded in the dorsal half. Dorsal margin straight, ventral margin slightly concave in the middle. Surface of the carapace ornamented with short spines arranged concentrically in the anterior half; posterior half with three well-developed rows of spines. The dorsal and ventral rows of spines parallel the dorsal and ventral margins respectively. Of these three rows, the ventral and central rows are more prominent. Between these two rows is a deep, almost smooth furrow. The subcentral tubercle is well-developed, and is set with 6–10 short stubby spines. In weathered specimens the ornamentation shows a reticulate pattern. The spines on weathering leave quadrate pits in their position surrounded by the bases of the spines (see Pl. 35, fig. 12). Pore canals and hinge normal for the genus.

*Horizon.*—Upper Eocene, Cooper Marl.

*Remarks.*—This species differs from the *H. evax* in being thickly and closely ornamented. The posterior end in *H. evax* has a tendency towards angulation while in *H. echinata* it tends to be subrounded.

Dimensions of paratype no. HVH 4701, a right valve: length .759 mm., height .417 mm.; paratype no. HVH 4702, a left valve: length .718 mm., height .442 mm.; holotype no. FGS S-5001, a complete carapace: length .759 mm., height .425 mm.; paratype no. USNM P-2054, a right valve: length .668 mm., height .400 mm. All type specimens are from locality no. 1.

Family uncertain
CLIMACOIDEA Puri, n. gen.

Type species: *Climacoidea plueurata* Puri, n. sp.

*Description.*—Carapace medium, subrectangular. Surface of the carapace ornamented with raised ridges which roughly run parallel with the outline of the carapace. Areas between ridges are like steps; these areas are wide, smooth, reticulate or pitted. Anterior margin wide, posterior margin nar-

row. Marginal pore canals few and straight. Line of concrescence coincides with the inner margin. Hinge in the right valve with an anterior large, lobate tooth, a large postjacent socket and a posterior lobate tooth, connected with a deep furrow. The connecting furrow is bounded both dorsally and ventrally with thin smooth bars. The ventral bar also goes around the anterior postjacent socket. Hinge in left valve with an anterior lobate tooth, and adjacent socket, a well-developed lunule, dorsal portion of which looks like a rounded tooth; and a posterior socket with base of tignum shaped like a rounded tooth. The anterior and posterior elements of the hingement are connected with tignum which is straight and narrow. Muscle scar pattern obscure; two close-spaced vertical rows of three scars observed in one specimen.

The generic name is derived from Greek, climac (κλῖμαξ), meaning a ladder, staircase.

*Horizon.*—"Pliocene," Caloosahatchee marl.

*Remarks.*—The general outline of the carapace resembles *Hemicythere* Sars but the hinge and ornamentation distinguish it.

### CLIMACOIDEA PLUEURATA Puri, n. sp.
Pl. 36, fig. 5–12

*Description.*—Carapace subrectangular, oblong in side view. Anterior end obliquely rounded above, broadly rounded below; slightly wavy in some specimens. Posterior end sharply rectangular below, oblique above. Surface of the carapace ornamented with ribs which run roughly parallel to the outline of the carapace. Central ribs have a tendency to be wavy and oblique. The dorsalmost rib starts at a point posterior to the anterior cardinal angle and goes all the way around the carapace until it nears the posterior cardinal angle where it deflects to the anterior and traverses the posterior half of the carapace. A second rib starts in the middle of the posterior end and traverses around the carapace until it joins the first row, then deflects anteroventrally and runs roughly parallel to the first rib. There are two U-shaped ribs, one with base of the U towards the posterior end. An additional rib slightly below the middle completes this zigzag pattern. Some specimens show slight deviation in the course of ribs but are in general parallel to the outline of the carapace. Hinge and pore canals normal to the genus.

The specific name is derived from Greek plueura (πλευρά), meaning rib.

*Horizon.*—"Pliocene," Caloosahatchee marl.

Dimensions of syntype no. HVH 4703, a left valve: length .642 mm., height .334 mm.; syntype no. FGS S-5002, a right valve: length .642 mm., height .334 mm.; syntype USNM P-2055, a complete carapace: length .659 mm., height .359 mm. All the types are from locality No. 4.

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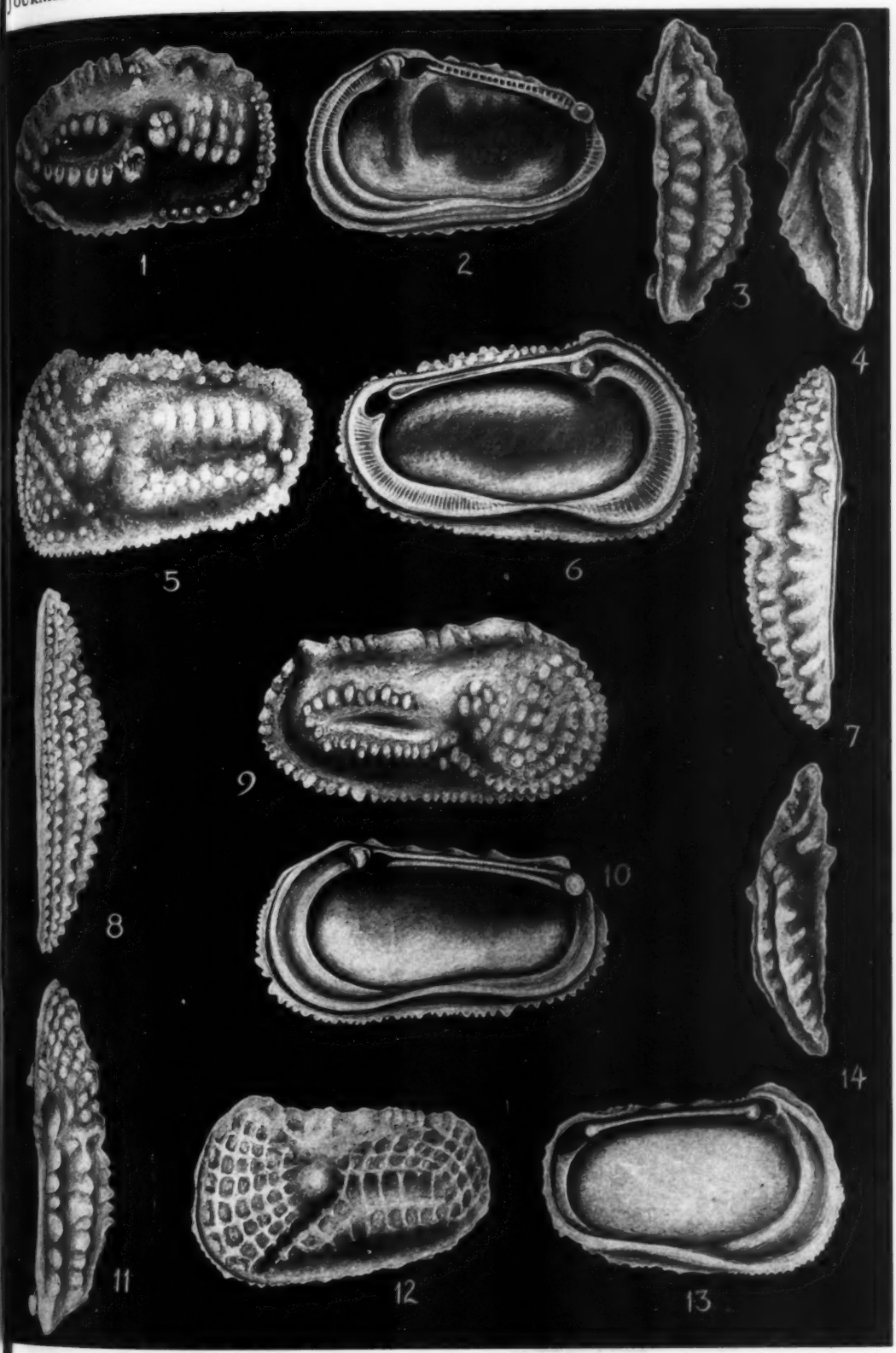
### EXPLANATION OF PLATE 35

All figures approximately ×65.

FIG. *1–8—Howella evax* (Ulrich & Bassler). *1*, right valve, plesiotype, HVH 4700, locality 2; *2*, inside view of same specimen; *3*, dorsal view of same specimen; *4*, ventral view of the same specimen; *5*, left valve, plesiotype, FGS S-5000, locality 3; *6*, inside view of same specimen; *7*, dorsal view of same specimen; *8*, ventral side of same specimen.

*9–14—Howella echinata* Puri, n. sp., locality 1. *9*, right valve, paratype, HVH 4701; *10*, inside view of same specimen; *11*, dorsal view of same specimen; *12*, left valve, paratype, HVH 4702; *13*, inside view of same specimen; *14*, dorsal view of same specimen.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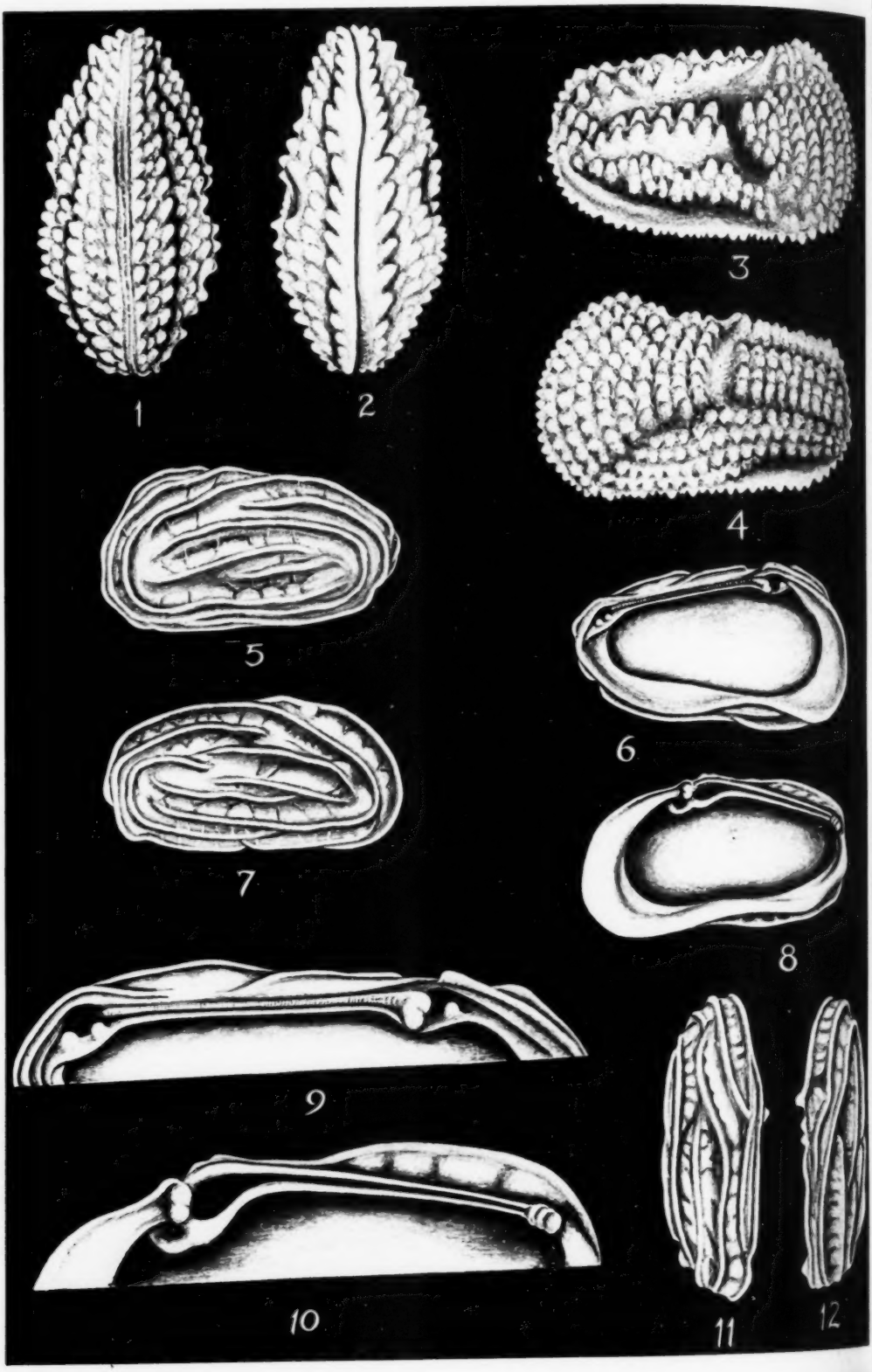
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## EXPLANATION OF PLATE 36

All figures approximately ×65, unless otherwise indicated.

FIG. *1–4—Howella echinata* Puri, n. sp., locality 1. *1*, holotype, FGS S-5001, ventral view of a complete carapace; *2*, dorsal view of same specimen; *3*, right valve view of same specimen; *4*, left valve view of same specimen.

*5–12—Climacoidea plueurata* Puri, n. gen., n. sp., locality 4. *5*, left valve, syntype HVH 4703; *6*, inside view of same specimen; *7*, right valve, syntype FGS S-5002; *8*, inside view of same specimen; *9*, syntype HVH 4703, (×130) showing detailed hinge structure; *10*, syntype FGS S-5002, (×130) showing detailed hinge structure; *11*, syntype HVH 4703, dorsal view; *12*, syntype FGS S-5002, dorsal view.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 2, P. 278–298, PL. 37–39, 5 TEXT-FIG., MARCH, 1956

# UPPER CRETACEOUS FORAMINIFERA, OSTRACODA, AND RADIOLARIA FROM MINNESOTA

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ABSTRACT—Microfossils are described and illustrated from the Cretaceous of two areas in central and southwestern Minnesota. Six new species of Foraminifera are established. The collections from the subsurface of Aitkin and Crow Wing counties are chiefly arenaceous Foraminifera that suggest a Cenomanian age for the containing strata. Foraminifera, Radiolaria, and an ostracode from Cretaceous outcrops in Lyon and Redwood counties suggest a correlation with the Niobrara formation (Coniacian-Santonian) of the western interior United States.

## INTRODUCTION

THE purpose of this report is to record the microfaunas obtained from several samples of Cretaceous rocks in central and southern Minnesota, to attempt generalized correlations with other Cretaceous microfaunas, and to suggest ecologic interpretations.

Cretaceous microfossils in Minnesota were first recorded from clays and boulder clays in Meeker and Koochiching counties (Woodward & Thomas, 1895). Most of the microfossils described in that report appear to be of Coniacian-Santonian age. However, changes have occurred in the generic assignments of many of the species identified by Woodward & Thomas, and a reexamination of the specimens (no longer extant), would be necessary to establish a definite age. Foraminifera were found in several exploratory drill holes between the Mesabi and Cuyuna iron ranges in 1943. George Gryc (unpublished report) made a preliminary study of these sediments but did not specifically identify the Foraminifera he found. He suggested, however, that the Foraminifera in the sediments indicated a Cretaceous age for the sediments and that in general they were similar to forms in the Taylor marl of Texas (Cushman & Waters, 1927) and the Navarro group of Mexico (White, 1928). This suggestion is believed to be in error.

The author examined many samples of Cretaceous and possible Cretaceous sediments on file at the University of Minnesota. Seven outcrop samples from the vicinity of Redwood Falls, were examined, but only one was found to contain microfossils. A sample thought to be from the "Sodergren Quarry" at North Redwood, just across Redwood River from Redwood Falls, yielded a microfauna consisting of several species of calcareous Foraminifera and a single ostracode specimen. A sample from Lyon County was found to contain a few Foraminifera and Radiolaria. Two samples from Brown County and one from near Austin in southcentral Minnesota were unfossiliferous. Samples from seven exploratory drill holes in northwestern Aitkin and northeastern Crow Wing counties were examined. The samples from four of these test holes were found to contain a microfauna consisting of Foraminfera, fish teeth, scales, and bone fragments.

## ACKNOWLEDGMENTS

Many of the outcrop samples used in this study were collected by R. E. Giles in 1928. In 1943, samples from five iron-ore test holes were sent to G. M. Schwartz, of the University of Minnesota, by C. J. Calvin, Great Northern Iron Ore Properties. The M. A. Hanna Company sent samples from two other test holes to J. W. Gruner, of the University of Minnesota. The author is grateful for the use of this material. George Gryc's unpublished report on the inter-iron-range core holes, written at the suggestion of F. F. Grout, provided useful information.

Acknowledgment is especially due F. M. Swain of the University of Minnesota, who brought this problem to the writer's attention, supervised the work and aided in the photography. His understanding of the problem and constructive criticism of the

work has made this report possible. Nicola Prokopovitch, Minnesota Geological Survey, gave many valuable suggestions and assisted in the preparation of the maps. Grace Beede, University of South Dakota, checked the specific names for correctness of usage. Finally, I would like to thank my wife, Betty Bolin, for typing the manuscript and for continued encouragement.

## CRETACEOUS STRATIGRAPHY OF MINNESOTA: GENERAL DISTRIBUTION

Sediments of Cretaceous age are known or inferred to form the bedrock of more than one-quarter of Minnesota (Text-fig. 1). Clastic sediments lie between the glacial drift and the Precambrian basement rock over most of the western half of southern Minnesota. These sediments consist of clays, silts, sands, and conglomerates. Thin beds of impure lignite are interbedded with the clays in places, indicating that swampy conditions prevailed at times (Thiel, 1944, p. 76). These deposits continue to the north where they have been penetrated by numerous water wells in the Red River Valley and farther east. There, they consist chiefly of clay shale with thin basal sands. At many places thin beds of lignite occur near the base (Allison, 1932, p. 5). The majority of these sediments in western Minnesota have been correlated with the Dakota sandstone on the basis of fossil plants found in shales at Springfield, and in sandstones along the Big Cottonwood River south of New Ulm (Lesquereux, 1895). In south central Stearns County, fossiliferous marine shales of apparent lower Cenomanian age overlie the terrestrial deposits. These shales are referred to the Coleraine formation. Foraminifera of probable Coniacian-Santonian age are figured and described in the present report from two outcrop samples in Lyon and Redwood counties. This suggests the presence of marine sediments correlative with the Niobrara formation in western Minnesota.

Widely scattered deposits of gravels, sands, and clays are found in the southeastern quarter of Minnesota. They have been classified as the Ostrander member of the Dakota formation (Stauffer and Thiel, 1933, p. 103). The Ostrander lies beneath glacial drift and rests on Devonian and older rocks.

In northcentral Minnesota Cretaceous beds are spread as a mantle on the uneven Precambrian surface. These sediments are for the most part buried beneath a cover of glacial drift which obscures their areal extent. On the Mesabi Range, sediments referred to the Coleraine formation (Berquist, 1944, p. 8) are exposed in the walls of some of the open pit mines from Virginia westward as far as Coleraine. The formation consists of a coarse basal conglomerate, derived largely from the underlying iron formation and other Precambrian rocks, which grades upward into ferruginous sandstone and shale. The sediments are probably largely of continental origin in the east, but grade westward into marine deposits bearing a dominantly molluscan fauna of Cenomanian age. Gray shale, sandy shale, and sand lie beneath 160 to 272 feet of glacial drift over a rather large area of unknown areal extent just north of the Cuyuna Range in Aitkin, Crow Wing, and possibly Cass counties. These sediments appear to be of nonmarine origin to the north and east, but consist for the most part of fossiliferous marine deposits. They may be equivalent to the Coleraine formation although the evidence suggesting this correlation is not conclusive. Scattered deposits of probable Cretaceous age lie beneath the drift in the Cuyuna iron ore district in southern Crow Wing County, and lignitic and bauxitic clays of Cretaceous age are exposed along the west bank of the Mississippi River, near the mouth of Two Rivers, Morrison County. In northern Koochiching County, strata bearing typical Cretaceous fossils crop out at several places in the banks of the Little Fork River. The unconsolidated nature of these beds makes it difficult to distinguish them from glacial or post-glacial lake sediments when fossils are lacking (Thiel, 1947 p. 151). Microfossils found in these beds (Woodward & Thomas, 1895) may be of Coniacian-Santonian age.

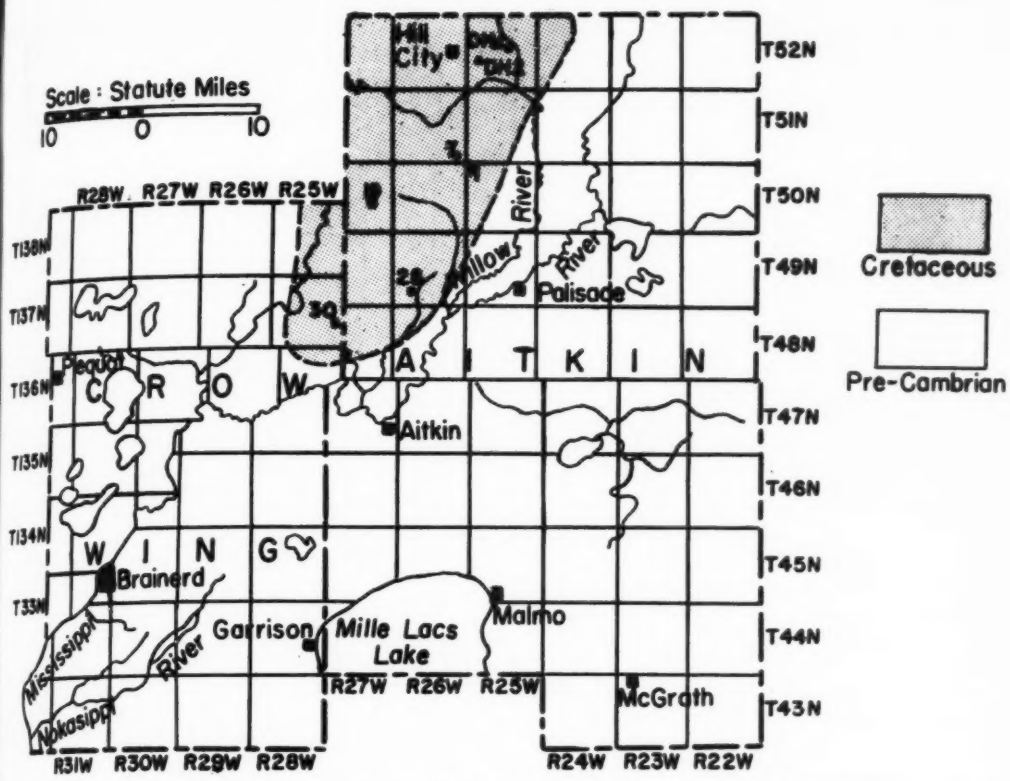
### Aitkin and Crow Wing Counties

No Cretaceous rocks are known to crop out in Aitkin or Crow Wing county. However, exploratory drilling for iron ore has revealed the presence of marine and probable nonmarine Cretaceous sediments between the Mesabi and Cuyuna ranges in

TEXT-FIG. *1*—Index map showing known or inferred distribution of Cretaceous rocks in Minnesota.

northeastern Crow Wing and northwestern Aitkin counties, and of scattered deposits of probable Cretaceous age on the Cuyuna Range in southern Crow Wing County.

Seven test holes drilled north of the Cuyuna iron ore district penetrated Cretaceous sediments, and core samples from them were studied during this investigation.




TEXT-FIG. 2—Schematic geologic map of Aitkin and Crow Wing counties, showing location of drill holes studied.

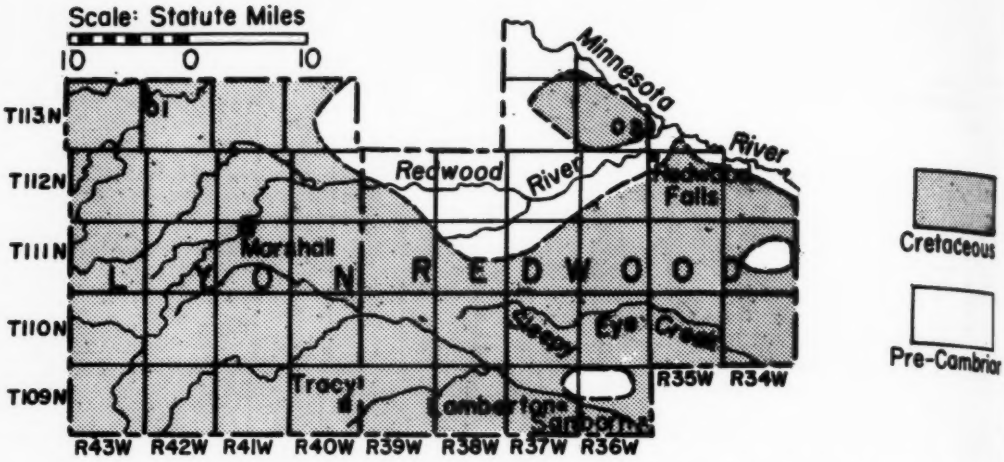
These test holes are located as shown on Text-fig. 2.

The sediments from drill holes 1 and 2 consist predominantly of poorly sorted quartz sand. The bottom twenty-two feet (285′–307′) in drill hole no. 1 is a very sandy clay with abundant tan, warty concretions, probably composed of manganosiderite. The sand is 132 feet thick in drill hole no. 1, but thins to 75 feet in drill hole no. 2 (Text-fig. 4). Fifty-five feet of fine grained ferruginous sand were encountered in test hole no. 28 beneath 200 feet of glacial drift. No fossils were found in the sands, and although it is not possible to establish definitely their Cretaceous age, they may be equivalent to the fossiliferous deposits found in the test holes to the south and west.

Marine fossiliferous sediments were encountered beneath glacial drift in test holes 1, 7, 19, and 30. These sediments consist of gray shale, sandy shale, and sand bearing a microfauna consisting of Foraminifera and fish teeth, scales, and bone fragments. The Foraminifera establish a Cretaceous age for the sediments, and suggest that they may be Cenomanian.

## Redwood and Lyon Counties

Cretaceous sediments lie beneath the glacial drift throughout most of Redwood and Lyon counties (Text-fig. 3). The Cretaceous rests on the Sioux quartzite in the southern part of those counties, and on granite to the north. The sediments consist predominantly of shale with thin layers of sandstone. At several places thin beds of impure lignite are interbedded with the shales. They are thickest in the southern and central parts of Lyon County, where up to 450 feet of Cretaceous is sometimes penetrated in water wells without reaching the base of the sediments. In the extreme northeastern corner of Lyon County and the northwestern part of Redwood County, drift probably rests directly on granite. Granite is exposed in the valleys of the Red-




TEXT-FIG. 3—Schematic geologic map of Redwood and Lyon counties, showing location of outcrop samples studied.

wood and Minnesota rivers in Redwood County, and in the northeastern part of that county only small irregular patches of Cretaceous sediments are resting on the uneven granite surface. Cretaceous rocks are exposed at places along the Redwood and Minnesota rivers, and also along some of the smaller streams throughout these two counties. Many of these exposures are small and may represent material reworked by glacial action. Most of these sediments appear to be nonmarine as they lack marine fossils and contain thin seams of lignite; they have been correlated with the Dakota sandstone. Microfossils of probable Santonian age, however, were found in two outcrop samples during this investigation. These outcrops may represent material reworked by glacial action, but if in place they establish the presence of marine Cretaceous sediments in the central Minnesota Valley.

## DISCUSSION OF THE FAUNA

Distinctive microfaunas were found in the two areas studied. Foraminifera are the dominant element in each, but they consist entirely of calcareous forms in the outcrop samples from Lyon and Redwood counties in contrast to the predominance of arenaceous forms in the subsurface samples from Aitkin and Crow Wing counties. In addition to Foraminifera, a few Radiolaria and one ostracode specimen were recovered from the outcrop samples. Fish teeth, scales, and bone fragments were the only other microfossils found in the subsurface samples.

The outcrop samples from Lyon and Redwood counties yielded a microfauna consisting of eleven species of calcareous Foraminifera, three species of Radiolaria, and one species of Ostracoda. Their distribution is shown by the following faunal lists:

Species found in the "Sodergren Quarry" sample:

Foraminifera:

*Gümbelina globulosa* (Ehrenberg)
*Gümbelina moremani* Cushman
*Gümbelina* cf. *G. striata* (Ehrenberg)
*Loxostomum cushmani* Wickenden
*Gyroidina* sp.
*Globigerina cretacea* d'Orbigny
*Planulina kansasensis* Morrow

Ostracoda:

*Cythereis* aff. *C. quadrialira* Swain

Species found in the sample from sec. 7, T113 N, R42W, Lyon County:

Foraminifera:

*Gümbelina globulosa* (Ehrenberg)
*Gümbelina pseudotessera* Cushman
*Gümbelina* cf. *G. striata* (Ehrenberg)
*Neobulimina* sp.
*Globigerina cretacea* d'Orbigny
*Globigerinella aspera* Ehrenberg
*Anomalina* sp.

Radiolaria:

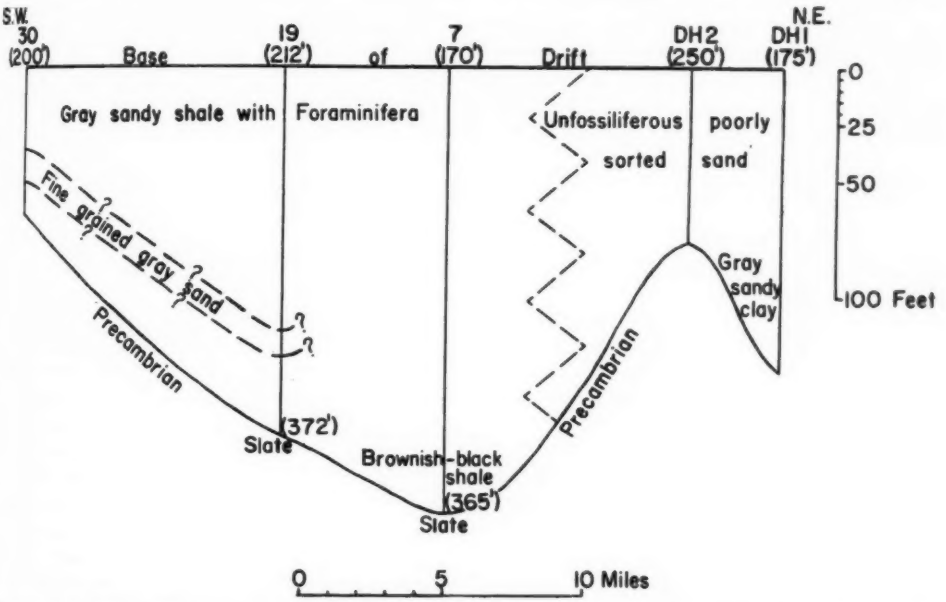
*Dictyocephalus* cf. *D. macrostoma* Rust
*Dictyomitra* sp.
*Dictyomitra* (*Dictyomitra*) cf. *D.* (*D.*) *multicostata* (Zittel)

This microfauna is striking because of the complete absence of arenaceous Foraminifera and the predominance of planktonic forms. The few benthonic species represented are found only rarely. Only three species of Foraminifera; *Gümbelina globulosa* (Ehrenberg), *Gümbelina* cf. *G. striata* (Ehrenberg), and *Globigerina cretacea* d'Orbigny; are common to both samples. However, these species are by far the most abundant in each sample. Seven of the eight identified species of Foraminifera are common in the Niobrara formation of Kansas, Nebraska, and South Dakota. *Gümbelina striata* (Ehrenberg), has not been reported from the Niobrara, but a similar species, *Gümbelina plummerae* Loetterle, is widely distributed in the formation. Five of the eight identified species; *Gümbelina globulosa* (Ehrenberg), *Gümbelina moremani* Cushman, *Loxostomum cushmani* Wickenden, *Globigerina cretacea* d'Orbigny, and *Globigerinella aspera* Ehrenberg; also range upward into the lower part of the overlying Pierre shale. The two identified species of Radiolaria have not been identified from the Niobrara formation, but both were reported by Rust (1892) from the lower Pierre shale of Manitoba, Canada. *Dictyocephalus macrostoma* Rust, has also been reported from sediments thought to be of upper Senonian age from California. The single ostracode species has been reported only from the Eutaw formation, Coniacian-Santonian, of North Carolina (Swain, 1952).

The Foraminifera found in the subsurface sediments from Aitkin and Crow Wing counties are predominantly arenaceous forms. Only two specimens of the calcareous species, *Globigerina washitensis* Carsey, were found, and both of these are fillings and perhaps partial replacements of the test by glauconite. A list of the Foraminifera follows (the numbers in parenthesis indicate the test holes in which each species occurs):

*Haplophragmoides* sp. (19)
*Haplophragmoides rudis*, n. sp. (1, 7, 19)
*Haplophragmoides formosum*, n. sp. (1, 7, 19)
*Ammobaculites* sp. (1)
*Ammobaculites ovatus*, n. sp. (1, 7, 19)
*Ammobaculites elongatus*, n. sp. (1, 7, 19)
*Ammobaculoides* spp. (19)
*Trochammina minnesotensis*, n. sp. (1, 7, 19, 30)
*Trochammina globosa*, n. sp. (1, 7, 19)
*Globigerina washitensis* Carsey (7, 30)

It is apparent from the distribution of the Foraminifera shown in the preceeding list that the fossiliferous sediments penetrated




TEXT-FIG. 4.—Generalized cross section of Cretaceous rocks, northwestern Aitkin and northeastern Crow Wing counties. Location of drill holes shown in Text-fig. 2. Numbers in parentheses indicate depth to top and bottom of Cretaceous.

in these test holes represent the same horizon. Foraminifera are by far the most abundant in test hole 19 but only two very rare species are restricted to this hole. Only two species were found in test hole 30, whereas Foraminifera were fairly common in test holes 1 and 7. *Trochammina minnesotensis*, n. sp., is the most abundant species in this microfauna, and is also the only species found in all four test holes. Many of the specimens found have been much distorted and flattened during compaction of the enclosing sediments. This is frequently the case with arenaceous species, and adds to the difficulty of identifying them. Those species which are represented by but few distorted specimens have not been assigned names. The better specimens are filled with tiny pyrite nodules to which they apparently owe their state of preservation.

The most striking characteristic of this microfauna is the fact that all of the arenaceous forms apparently represent new species. The only previously described associated species is the calcareous form *Globigerina washitensis* Carsey, which has been reported previously only from the Lower Cretaceous Washita group of Texas. However this species is represented by only two specimens and it may not represent part of the biocoenose. This fauna, as a whole, is closely related to those of the Lloydmaster shale of Canada (Wall, 1951) and the Pepper shale of Texas (Loeblich, 1946), although none of the species appears to be the same.

## ECOLOGY

The Cretaceous microfauna from the test holes in Aitkin and Crow Wing counties is dominated by species of arenaceous genera which are known to adapt themselves to variable conditions and are found in many marine environments. However this particular microfauna is of ecologic significance, because, taking into account the lithology of the enclosing sediments, it suggests a very nearshore, probably cold, brackish water environment. Factors indicating these conditions are:

1. The presence of many rather coarsely arenaceous Foraminifera indicates shallow water.
2. As shown in Text-figure 4, unfossiliferous sands of probable terrestrial origin to the north and east grade into marine strata containing Foraminifera to the south and west, indicating nearshore deposition of the fossiliferous sediments.
3. There are no exclusively deep water forms in the microfauna.
4. The almost total absence of calcareous forms would indicate a cool water or lowered pH or both.
5. The presence of pyrite filling in the tests suggests rather toxic conditions such as might be expected in a nearshore embayed coast having poor circulation.
6. The nearly complete absence of planktonic forms, which are common in many Cretaceous microfaunas, suggests brackish water with no open connection to the sea. If an open connection with the sea were present, numerous planktonic forms would have floated in and be present in the thanatocoenose.

It is difficult to interpret the ecology of a microfaunal assemblage dominated by planktonic forms such as that found in the shale samples from Lyon and Redwood counties. The relative abundance of planktonic forms and very rare occurrence of benthonic forms would indicate adverse bottom conditions. The specimens comprising this microfauna, both planktonic and benthonic forms, are much smaller than the average for the species.

## CONCLUSIONS

The microfauna from the two fossiliferous outcrop samples in Lyon and Redwood counties establishes an Upper Cretaceous age for these sediments. Of the eight species of Foraminifera identified from these samples, seven are very common in the Niobrara of Kansas, Nebraska, and South Dakota, and a form very similar to the other species is also found in that formation. One of these species, *Loxostomum cushmani* Wickenden, is limited to the upper part of the Smokey Hill member of the Niobrara formation. Five of the species also range up into the lower part of the overlying Pierre shale of Campanian age. The two identified species of Radiolaria were reported by Rust (1892) from the lower Pierre shale of Manitoba, Canada, and the single ostrocode species has been reported previously only

from the Eutaw formation from North Carolina. The Eutaw was correlated with the Austin chalk and Niobrara formation by Stephenson and Reeside (1938, p. 1631, fig. 2). The microfauna of the lower Pierre shale contains a much larger proportion of arenaceous forms than the Niobrara, and arenaceous forms are completely absent in the samples studied. The micropaleontological evidence shows therefore, that these sediments are equivalent to either the Niobrara formation or the basal part of the Pierre shale, with the preponderance of evidence suggesting a correlation with the upper Niobrara.

It is not known whether the outcrops sampled represent sediments *in situ* or material reworked by glacial action. If this material has been reworked by glacial ice, the presence of these outcrops would indicate that the Niobrara formation was deposited in this region, and would thereby extend the known limits of the Niobrara sea eastward into Minnesota. If these outcrops are in place, they would in all probability represent remnants of the Niobrara formation resting on the nonmarine sediments correlated with the Dakota sandstone. The possibility that all or part of these underlying sediments might also be Niobrara is not likely because of their terrestrial origin.

It is not possible to make a definite correlation of the subsurface sediments in Aitkin and Crow Wing counties with those of any other region because of the dominance of new species in the microfauna. However this microfauna, as a whole, is closely related to those of the Cenomanian Pepper shale of Texas and Lloydmaster shale of Canada. This resemblance would suggest, although not definitely establish, a Cenomanian age for the subsurface sediments studied. There is no similarity between this Aitkin County microfauna and the arenaceous species of the lower Pierre shale observed by the author in central and southeastern South Dakota. Species of *Pseudoclavulina*, *Clavulinoides*, *Pseudogaudryinella*, *Dorothia*, and *Ammodiscus* are found in the lower Pierre, and none of these genera is represented in the present microfauna.

The Coleraine formation of the Mesabi range is presently also assigned a Cenomanian age (Cobban and Reeside, 1952, chart 10b). Both the Coleraine and the Aitkin-Crow Wing nonmarine eastern facies grade westward into marine deposits.

### Despository of Specimens

The type specimens will be housed in the U. S. National Museum (USNM).

## SYSTEMATIC DESCRIPTIONS

Order FORAMINIFERA d'Orbigny, 1826
Family LITUOLIDAE Brady, 1884
Subfamily HAPLOPHRAGMIINAE Cushman, 1927
Genus HAPLOPHRAGMOIDES Cushman, 1910

### HAPLOPHRAGMOIDES sp.
Pl. 37, fig. 2a,b

Test comparatively large, much compressed, periphery slightly lobulate in later part, planispirally coiled, becoming slightly evolute, with a large, shallow umbilicus on each side; chambers not very distinct, increasing regularly and quite rapidly in size as added, eight in final convolution; sutures distinct on moistened specimen, last few slightly depressed, earlier ones flush with surface, straight or very slightly arched backwards; wall arenaceous, very coarse and somewhat roughly finished on last few chambers; aperture not clearly observed but appears to be an arched opening at base of final chamber.

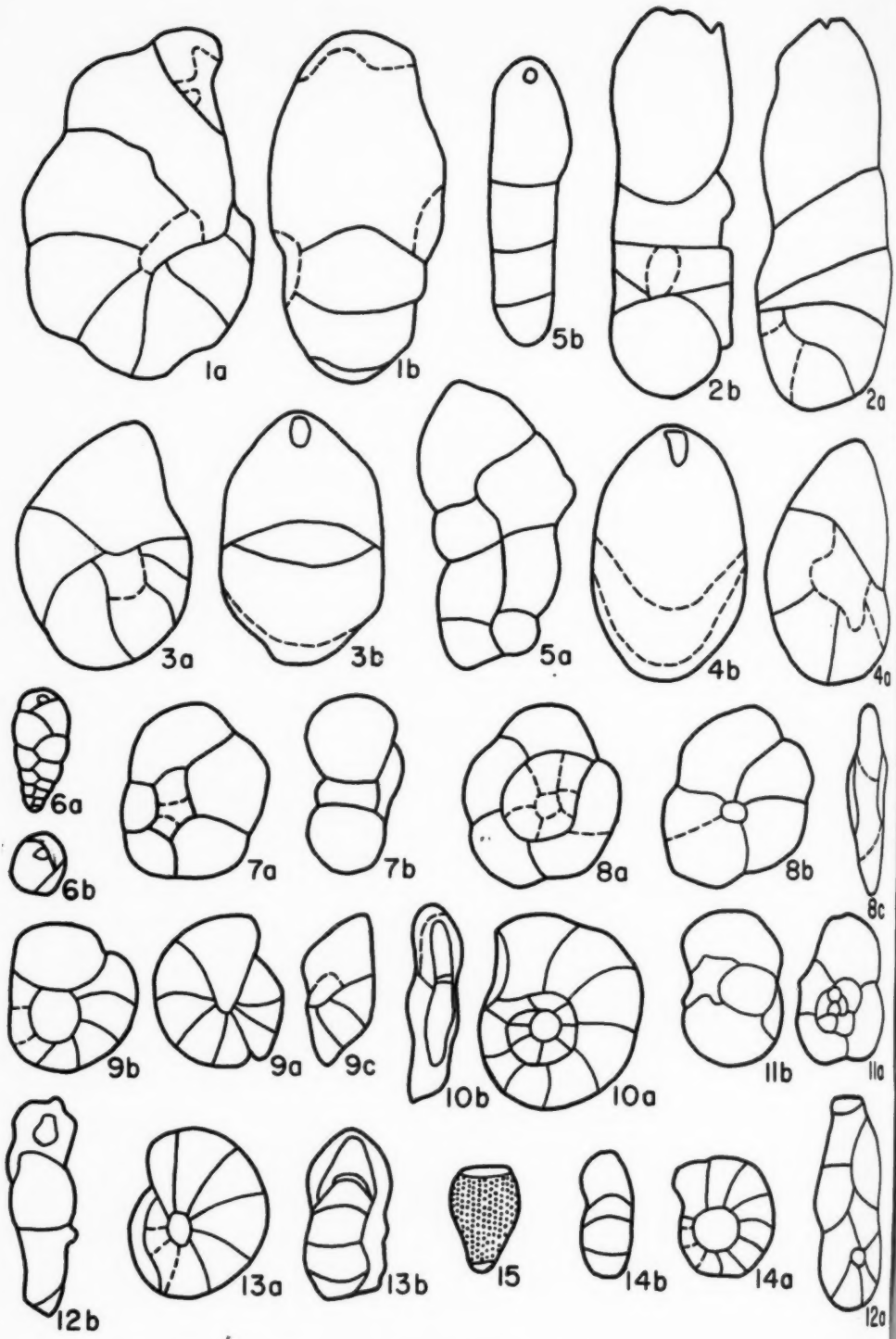
*Dimensions.*—Greatest diameter of figured specimen .62 mm., least diameter .48 mm., thickness .17 mm.

*Remarks.*—This species is quite similar to *Haplophragmoides rudis*, n. sp., but is larger and has a more coarsely arenaceous test.

*Occurrence.*—The figured specimen, the only known representative of this species, was found in test hole no. 19 at a depth of 252 to 257 feet.

### HAPLOPHRAGMOIDES RUDIS Bolin, n. sp.
Pl. 37, fig. 3–6

Test medium sized and compressed. Most specimens exhibit a much flattened test; periphery subacute, slightly lobulate in later portion; shallowly umbilicate, umbilicus of one or both sides sometimes filled with a matrix of foreign material; planispirally coiled, tending to become evolute in later stages. Chambers distinct, numerous, eight to eight and one-half in final whorl, increas-




TEXT-FIG. 5—Drawings of Foraminifera and Radiolaria, ×75.
*1a,b—Ammobaculites* sp. Side and peripheral views, Test Hole No. 19 at 210–215 feet, Aitkin Co.

ing rather irregularly in size as added; sutures distinct, very slightly depressed, straight to slightly arched backwards, wall finely arenaceous and smoothly finished; aperture a crescentic opening at base of final chamber, extending from equatorial plane one-third to one-half of distance to umbilicus.

*Dimensions.*—Greatest diameter of holotype (Pl. 37, fig. 3) .50 mm., least diameter .42 mm., thickness .18 mm. Greatest diameter of paratype (Pl. 37, fig. 4) .53 mm., least diameter .47 mm., thickness .15 mm. Greatest diameter of paratype (Pl. 37, fig. 5) .43 mm., least diameter .37 mm., thickness .17 mm. Greatest diameter of paratype (Pl. 37, fig. 6) .40 mm., least diameter .32 mm., thickness .15 mm.

*Remarks.*—This species is similar to *Haplophragmoides* ST-850-A Wall (1951), and *Haplophragmoides collyra* Nauss, both of which occur in the early Upper Cretaceous of Canada. However, both of these species have more inflated chambers, and a more rounded and lobulate periphery. Wall's species has fewer chambers in the final whorl, seven compared to eight or eight and one-half, and has a triangular aperture.

*Occurrence.*—The figured specimens are all from test hole no. 19. The holotype was found at a depth of 227 to 232 feet, figure 4 (Pl. 37) at a depth of 292 to 297 feet, and figures 5 and 6 (Pl. 37) at a depth of 222 to 227 feet. This species is by far the most abundant representative of the genus. It is common to abundant in test hole no. 19, fairly common in test hole no. 7, and rare in test hole no. 1. It was not found in test hole no. 30.

HAPLOPHRAGMOIDES FORMOSUM
Bolin, n. sp.
Pl. 37, fig. 7–9

Test small, with rounded periphery, planispirally coiled, involute, with a small, relatively deep umbilicus on each side, chambers distinct, triangular in shape, increasing regularly in size as added, eight in final whorl; sutures distinct, radial, straight, very slightly depressed; wall finely arenaceous and smoothly finished; aperture an arched opening at base of final chamber, in median line.

*Dimensions.*—Greatest diameter of holotype (Pl. 37, fig. 9) .23 mm., least diameter .20 mm., thickness .12 mm. Greatest diameter of paratype (Pl. 37, fig. 8) .30 mm., least diameter .27 mm., thickness .15 mm. Greatest diameter of flattened paratype (Pl. 37, fig. 7) .33 mm., least diameter .27 mm.

*Remarks.*—This species differs from *Haplophrogmoides rudis*, n. sp., in being smaller and completely involute, also in having distinctly triangular chambers and the aperture in the median line. *Haplophragmoides linki* Nauss, from the middle part of the Cenomanian Lloydmaster shale of Canada, has a larger umbilicus, more depressed sutures, and a more broadly rounded periphery.

*Occurrence.*—The holotype is from test hole no. 7 at a depth of 195 to 200 feet. The paratype shown in figure 8 (Pl. 37) is from test hole no. 19 at a depth of 232 to 237 feet, and that shown in figure 7 (Pl. 37) is from test hole no. 1 at a depth of 195 to 200 feet. This species is rare to fairly common in many samples from test holes 7 and 19, and is rare in test hole no. 1.

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*2a,b—Ammobaculites elongatus* Bolin, n. sp. Side and peripheral views, Test Hole No. 19, 277 to 282 feet, Aitkin Co.

*3a-4b—Ammobaculites ovatus* Bolin, n. sp. Test Hole No. 19, Aitkin Co. *3*, side and peripheral views, 222 to 227 feet. *4*, side and peripheral views, 277 to 282 feet.

*5a,b; 12a,b—Ammobaculoides* spp. Test Hole No. 19, Aitkin Co. *5*, side and peripheral views, 292 to 297 feet. *12*, side and peripheral views, 357 to 362 feet.

*6a,b—Neobulimina* sp. Side and apertural views, Sec. 7, T113N, R42W, Lyon Co.

*7a,b—Trochammina globosa* Bolin, n. sp. Dorsal, ventral, and peripheral views, Test Hole No. 7, 240 to 245 feet, Aitkin Co.

*8a-c—Trochammina minnesotensis* Bolin, n. sp. Dorsal, ventral, and peripheral views, Test Hole No. 7, 240 to 245 feet, Aitkin Co.

*9a-c—Gyroidina* sp. Dorsal, ventral, and peripheral views, "Sodergren Quarry," North Redwood, Redwood Co.

*10a,b;14a,b—Planulina kansaensis* Morrow. *10*, ventral and peripheral views, "Sodergren Quarry," North Redwood, Redwood Co. *14*, dorsal view, Sec. 7, T113N, R42W, Lyon Co.

*11a,b—Globigerina washitensis* Carsey, Dorsal and peripheral views, Test Hole No. 30, 235 to 240 feet, Crow Wing Co.

*13a,b—Anomalina* sp. Ventral and peripheral views, Sec. 7, T113N, R42W, Lyon Co.

*15—Dictyocephalus* cf. *D. macrostoma* Rust. Sec. 7, T113N, R42W, Lyon Co.

Genus AMMOBACULITES Cushman, 1910

AMMOBACULITES sp.

Pl. 37, fig. 1a,b; Text-fig. 5—1a,b

Test large, somewhat compressed and elongate, planispirally coiled, tending to uncoil in later portion, periphery rounded, slightly lobulate; chambers rather indistinct, somewhat inflated, last few greatly elongated, seven or eight in final whorl; sutures rather indistinct, slightly depressed, early ones radial and straight, last few arched backwards; wall coarsely arenaceous, with distinct angular fragments; aperture a rather large opening near apex of final chamber.

*Dimensions.*—Greatest diameter of figured specimen .77 mm., least diameter .53 mm., thickness .38 mm.

*Remarks.*—The nature of the coiling in this specimen closely resembles that found in *Haplophragmoides*, but the position of the aperture reveals that it is an *Ammobaculites*. Because only one specimen with a broken final chamber was found, a specific name is not assigned.

*Occurrence.*—This specimen is from test hole no. 1 at a depth of 210 to 215 feet.

AMMOBACULITES OVATUS Bolin, n. sp.

Pl. 37, fig. 10,11; Text-fig. 5—3a–4b

Test medium sized, elongate ovate in side view, only slightly compressed, planispirally coiled and involute, but showing a marked tendency toward uncoiling in later portion, periphery rounded; chambers distinct only when specimen is moistened, about four and one-half in final whorl, increasing quite rapidly in size as added, final one much elongated; sutures rather indistinct, very slight depressed, curved; wall rather coarsely arenaceous but quite smoothly finished; aperture a large oval opening at outer periphery of final chamber.

*Dimensions.*—Greatest diameter of holotype (Pl. 37, fig. 11) .48 mm., least diameter .38 mm., thickness .32 mm. Greatest diameter of paratype (Pl. 37, fig. 10) .47 mm., least diameter .35 mm., thickness .27 mm.

*Remarks.*—Nothing similar to this species was found in the literature, but it tends to grade into *Ammobaculites elongatus*, n. sp., through the development of an uncoiled portion and a terminal aperture.

*Occurrence.*—The holotype and paratype are both from test hole no. 19. The holotype at a depth of 222 to 227 feet and the paratype at a depth of 277 to 282 feet. Two specimens of this species were found in test hole no. 1, and it occurs rarely in test holes 7 and 19.

AMMOBACULITES ELONGATUS Bolin, n. sp.

Pl. 38, fig. 1,2; Text-fig. 5—2a,b

Test quite large, somewhat compressed, ovate in end view, early portion involutely coiled, later portion uniserial; chambers of coiled portion rather indistinct, about four in outer whorl, uniserial chambers distinct, slightly inflated, three or four in number, increasing rapidly in size with final one flattened and appearing much larger than normal; sutures of coiled portion rather indistinct, radial, in uniserial portion distinct, slightly depressed, oblique and somewhat curved; wall arenaceous, composed of poorly sorted angular particles, amount of cement relatively small and surface somewhat roughly finished; aperture terminal, ovate.

*Dimensions.*—Length of holotype (Pl. 38, fig. 2) .77 mm., breadth of coiled portion .30 mm., thickness .25 mm. Length of paratype (Pl. 38, fig. 1) .77 mm., breadth of coiled portion .33 mm., thickness .25 mm.

*Remarks.*—This species differs from *Ammobaculites obscurus* Loeblich, from the Cenomanian Pepper shale of Texas, in being larger, and in having more oblique and slightly curved sutures in the uniserial portion. It appears similar to *Flabellammina* ST-937-A Wall (1951, p. 61), from the Lloydmaster shale of Canada, but it does not have as oblique or as arcuate sutures as that species, and is probably not as compressed.

*Occurrence.*—Both figured specimens are from test hole no. 19, the holotype at a depth of 342 to 347 feet and the paratype at a depth of 277 to 282 feet. This species is fairly common to common in many of the samples from test hole no. 19, rare in some samples from test hole no. 7, and was found to be rare in two samples from test hole no. 1.

Family TEXTULARIIDAE Brady, 1884

Subfamily SPIROPLECTAMMININAE Cushman, 1927

Genus AMMOBACULOIDES Plummer, 1932

AMMOBACULOIDES spp.

Pl. 38, fig. 3–5; Text-fig. 5—5a,b; 12a,b

Several specimens of *Ammobaculoides* are grouped here although they show considerable variation.

Test small to medium sized, flattened, elongate, early portions involutely coiled, then biserial, and becoming uniserial in final stages; chambers rather indistinct, increasing in size as added quite rapidly so in some specimens, two to six or more chambers in biserial stage, only one showing uniserial arrangement; sutures indistinct in most specimens, somewhat depressed in later part; test composed of poorly sorted angular fragments, with little cement and quite roughly finished; aperture a slit-like terminal opening, indistinct.

*Dimensions.*—Length of incomplete specimen (Pl. 38, fig. 3) .55 mm., breadth .30 mm., thickness .18 mm. Length of hypotype (Pl. 38, fig. 4) .66 mm., breadth .35 mm. Length of hypotype (Pl. 38, fig. 5) .41 mm., breadth .8 mm., thickness .12 mm.

*Remarks.*—The specimen illustrated in figure 5 (Pl. 38) is somewhat similar to *Ammobaculoides phalus* Loeblich and Tappan, from the Lower Cretaceous Kiowa shale of Kansas. However, it is larger and coarser grained than that species, and is broader in relation to length. No previously described species were found to be similar to the other two figured specimens.

*Occurrence.*—Figures 3 and 4 (Pl. 38) are from a depth of 292 to 297 feet in test hole no. 19, and figure 5 (Pl. 38) is from a depth of 257 to 362 feet.

Family TROCHAMMINIDAE Cushman, 1927
Subfamily TROCHAMMININAE
Brady, 1884
Genus TROCHAMMINA Parker and
Jones, 1859

TROCHAMMINA MINNESOTENSIS
Bolin, n. sp.
Pl. 38, fig. 7a–c; Text-fig. 5—8a–c

Test medium sized, much flattened, slightly biconvex or with one side flat, periphery sharp, slightly lobulate, trochospirally coiled, about two and one-half whorls visible on dorsal side, with a small ventral umbilicus; chambers quite indistinct, increasing gradually in size throughout, five in ultimate whorl, chambers usually collapsed centrally resulting in raised margins, particularly on ventral side; sutures rather indistinct, somewhat depressed, arched backwards on dorsal side, nearly straight on ventral; wall finely arenaceous, surface smooth, shell wall very delicate; aperture not clearly observed.

*Dimensions.*—Greatest diameter of holotype .30 mm., least diameter .29 mm., thickness .10 mm.

*Remarks.*—This species is very similar to *Trochammina wickendeni* Loeblich, from the type locality of the Pepper shale in Texas. It is not as smoothly finished as that species, and does not have as distinct or as depressed sutures.

*Occurrence.*—The holotype is from test hole no. 7 at a depth of 240 to 245 feet. This is the most common and widespread species in the test hole samples, being found in all of the samples from test holes 1, 7, and 19, and in most of the samples from test hole no. 30. However, many of the specimens placed here are so flattened and distorted that their identification is in doubt.

TROCHAMMINA GLOBOSA Bolin, n. sp.
Pl. 38, fig. 8a–9b; Text-fig. 5—7a,b

Test small, trochoid, with a slightly convex to flat spire of two to two and one-half whorls on dorsal side, and a fairly large, shallow, ventral umbilicus; periphery broadly rounded, slightly lobulate throughout; chambers indistinct in early portion, distinct in final whorl, five in number, increasing regularly in size as added; sutures distinct, slightly depressed, gently curved on dorsal side, radial and straight on ventral; wall arenaceous, smoothly finished; aperture not definitely observed, apparently an arched opening which extends into umbilicus from final chamber.

*Dimensions.*—Greatest diameter of holotype (Pl. 38, fig. 9) .33 mm., least diameter .28 mm., thickness .20 mm. Greatest diameter of paratype (Pl. 38, fig. 8) .33 mm., least diameter .28 mm., thickness .20 mm.

*Remarks.*—This species is more inflated, and has more globular chambers than any previously described species of the genus.

*Occurrence.*—The holotype and paratype are both from test hole no. 19, at depths of 252 to 257 feet, and 317 to 322 feet respectively. This distinctive species is rare in some of the samples from test holes 1, 7, and 19.

Family HETEROHELICIDAE Cushman, 1927
Subfamily GÜMBELININAE
Cushman, 1927
Genus GÜMBELINA Egger, 1899

GÜMBELINA GLOBULOSA (Ehrenberg)
Pl. 38, fig. 10–11b, 14a–b, 16
*Textularia globulosa* EHRENBERG, 1838, Abhandl.

K. pruess., Akad., Wiss. Berlin, p. 135, pl. 4, fig. B.

*Gümbelina globulosa* EGGER, 1899, Abhandl. kon. bay., Akad., Wiss. Munchen, kl. 2, vol. 21, pt. 1, p. 32, pl. 14, fig. 43. CUSHMAN, 1946, U.S.G.S. Prof. Pap. 206, p. 105, pl. 45, fig. 9–15; ——, 1948, Foraminifera, Ed. 4, key pl. 26, fig. 6a,b; ——, 1948, Maryland Dept. Geol., Mines and Water Res. Bull. 2, p. 258, pl. 24, fig. 9; ——, 1949, U.S.G.S. Prof. Pap. 221-A, p. 7, pl. 3, fig. 23. YOUNG, 1951, Jour. Paleontology, vol. 25, p. 63, pl. 14, fig. 12,23–26.

Test elongate, V-shaped, tapering uniformly to pointed initial end, periphery lobulate throughout, more strongly so in later portion, earliest stage coiled, then biserial; chambers distinct, globular and inflated, increasing in size throughout, more rapidly so toward apertural end; sutures distinct, depressed, slightly oblique; wall smooth, finely perforate; aperture a broad arched opening at base of final chamber, with a thickened, smooth lip.

*Dimensions.*—Length of hypotype (Pl. 38, fig. 10) .39 mm., width .25 mm., thickness .15 mm. Length of hypotype (Pl. 38, fig. 11) .29 mm., width .23 mm., thickness .14 mm. Length of hypotype (Pl. 38, fig. 14) .19 mm., width .15 mm., thickness .09 mm. Length of hypotype (Pl. 38, fig. 16) .40 mm., width .31 mm., thickness .18 mm.

*Remarks.*—It is di.ficult to distinguish this species from *Gümbelina reussi* Cushman, and characteristics of the two apparently grade into each other. *G. reussi* is described as having the periphery of the early part complete, and the later chambers clearly set off from one another with a triangular indented area between. The specimens figured and described as *Textularia globulosa* by Woodward & Thomas from clays and chalky limestones in Meeker County, Minnesota, apparently belong to this species.

*Occurrence.*—The specimens shown in figures 10 and 16 (Pl. 38) are from the Redwood County sample, and those shown in figures 11 and 14 (Pl. 38) are from the Lyon County sample. This species is widely distributed in the Upper Cretaceous of America and Europe. Morrow found it to occur throughout the Colorado group in Kansas, and Loetterle reported it from the Niobrara (Coniacian and Santonian) and lower Pierre (lower Campanian) in Kansas, Nebraska, and South Dakota. It is fairly common in the samples from Lyon and Redwood counties.

### GÜMBELINA MOREMANI Cushman
Pl. 38, fig. 15a,b

*Gümbelina moremani* CUSHMAN, 1938, Cushman Lab. Foram. Research Contr., vol. 14, p. 10, pl. 2, fig. 1–3; ——, 1946, U.S.G.S., Prof. Pap. 206, p. 103, pl. 44, fig. 15–17.

Test very elongate, gradually tapering throughout or attaining maximum breadth at penultimate pair of chambers, periphery lobulate throughout; chambers distinct, numerous, subglobular, increasing slowly in size as added; sutures distinct, depressed, nearly perpendicular to axis; wall smooth, finely perforate; aperture a high arched opening at base of final chamber, with a smooth lip which may project as a flange at the sides onto the preceding chamber. The figured speciman appears to have an incompletely developed final chamber.

*Dimensions.*—Length of hypotype .44 mm., width .21 mm., thickness .12 mm.

*Remarks.*—This species is more elongate than *Gümbelina globulosa* Ehrenberg, and has more chambers and a more gradually tapering test than that species.

*Occurrence.*—The figured specimen is from the "Sodergren Quarry" at North Redwood. This species occurs chiefly in the Eagle Ford shale (Turonian) of the Gulf Coast region, but has been reported also from the Austin chalk (Coniacian and Santonian). Morrow reported it from the Colorado group in Kansas, and it occurs in the Niobrara of South Dakota. It was found to be rare in the samples from Lyon and Redwood counties.

### GÜMBELINA PSEUDOTESSERA Cushman
Pl. 38, fig. 13

*Gümbelina tesera* CUSHMAN, 1932 [not *G. tessera* Cushman, 1936, nor *Grammostomum tessera* (Ehrenberg)], Jour. Paleontology, vol. 6, p. 338, pl. 51, fig. 4,5.

*Gümbelina pseudotessera* CUSHMAN, 1938, Cushman Lab. Foram. Research Contr., vol. 14, p. 14, pl. 2, fig. 19–21; ——, 1946, U.S.G.S. Prof. Pap. 206, p. 106, pl. 45, fig. 15–20.

Test small, compressed, about one and one-half times as long as broad, with greatest breadth at final pair of chambers, tapering rather rapidly to bluntly pointed initial end, periphery lobulate throughout, more strongly so in later portion; chambers distinct, slightly inflated, broader than high, final pair much broader and slightly curved; sutures depressed, final ones slightly curved; wall smooth, finely perforate; aperture a

high arched opening at base of final chamber, with a narrow lip and distinct flanges on each side.

*Dimensions.*—Length of hypotype .23 mm., breadth .15 mm., thickness .07 mm.

*Remarks.*—This species differs from *Gümbelina globulosa* (Ehrenberg), in the compressed test, shape of the later chambers, and curved sutures in the later portion.

*Occurrence.*—The species ranges throughout the Austin chalk (Coniacian and Santonian) and Taylor formation (lower Campanian). A few specimens were found in the sample from Lyon County.

GÜMBELINA cf. G. STRIATA (Ehrenberg)

Pl. 38, fig. 12a,b; 17a,b

*Textularia striata* Ehrenberg, 1838, Abhandl. K. preuss., Akad., Wiss. Berlin, p. 135, pl. 4, fig. 1a,2a,3a.

*Gümbelina striata* EGGER, 1899, Abhandl. Kon. bay., Akad., Wiss. Munchen, kl. 2, vol. 21, p. 33, pl. 4, fig. 37–39 (not 5–7,10,11). CUSHMAN, 1946, U.S.G.S., Prof. Pap. 206, p. 104, pl. 45, fig. 4,5; ——, 1948, Maryland Dept. Geol., Mines and Water Res. Bull. 2, p. 258, pl. 24, fig. 3; ——, 1949, U.S.G.S., Prof. Pap. 221-A, p. 7, pl. 3, fig. 24.

Test relatively small, tapering, more strongly so in early portion, periphery lobulate throughout; chambers distinct, inflated, globular, especially in later part; sutures distinct, depressed, slightly oblique; wall ornamented with fine longitudinal costae which become weaker on final chambers of most specimens, some with last chambers smooth or ornamented by fine perforations in longitudinal rows; aperture a large, low opening at base of final chamber, with a smooth, thickened rim.

*Dimensions.*—Length of hypotype (Pl. 38, fig. 12) .34 mm., width .25 mm., thickness .17 mm. Length of hypotype (Pl. 38, fig. 17) .23 mm., width .17 mm., thickness .11 mm.

*Remarks.*—This species differs from *Gümbelina globulosa* (Ehrenberg), in the presence of the longitudinal costae, and in having a less rapidly tapering test. *G. castulata* Cushman, has much stronger costae, is smaller, has a compressed test, and lower and broader chambers. *G. plummerae* Loetterle, is larger, much thicker in relation to length and breadth, has more inflated chambers, and usually has more strongly developed longitudinal costae.

The specimens referred to here are not as elongate as those placed in the species by Cushman; however, they agree well in other characteristics with the species, and are much more closely allied to it than to any other described form.

*Occurrence.*—The specimen illustrated in figure 12 (Pl. 38) is from Redwood County, while that in figure 17 (Pl. 38) is from Lyon County. *Gümbelina striata* (Ehrenberg), is found throughout the Austin chalk and Taylor formation, and it extends up into the Navarro group (upper Campanian and lower Maestrichtian age) in the Gulf Coast region. The specimens included here are common in the material from Redwood County and rare in that from Lyon County.

Family BULIMINIDAE Cushman, 1927
Subfamily BULIMININAE Cushman, 1927
Genus NEOBULIMINA Cushman and Wickenden, 1928

NEOBULIMINA sp.

Pl. 38, fig. 6a,b; Text-fig. 5—6a,b

Test small, elongate, two to two and one-half times as long as broad, somewhat fusiform, largest portion of test triserial, consisting of up to 10 chambers, becoming biserial in adult; chambers distinct, somewhat inflated, sub-globular; sutures distinct and depressed; wall coarsely perforate, nearly reticulate in some specimens; aperture at base of last formed chamber, in early triserial stage a high arched opening, nearly circular in adult biserial stage.

*Dimensions.*—Length of hypotype .22 mm., breadth .11 mm.

*Remarks.*—The specimens described here are quite similar to some referred to *Neobulimina canadensis* Cushman & Wickenden, by Cushman (1946, p. 125, pl. 52, fig. 11). However, in none of the few specimens observed here is the adult biserial stage as well developed as in typical specimens of *N. canadensis*. In addition, that species has a "comma-shaped" aperture in contrast to the broader and nearly circular aperture exhibited by these specimens.

*Occurrence.*—A few specimens of this species were found in the Lyon County sample.

Subfamily VIRGULININAE Cushman, 1927
Genus LOXOSTOMUM Ehrenberg, 1854

LOXOSTOMUM CUSHMANI Wickenden

Pl. 38, fig. 18a,b

*Loxostomum cushmani* WICKENDEN, 1932, Royal Soc. Canada. Trans., 3d ser., vol. 26, sec. 4, p. 91, pl. 1, fig. 6a,b.

*Loxostoma clavatum* CUSHMAN, 1932 (not Cushman, 1927), Jour. Paleontology, vol. 6, p. 340, pl. 51, fig. 8a,b.

*Loxostoma cushmani* CUSHMAN & DEADERICK, 1942, Cushman Lab. Foram. Research Contr., vol. 18, p. 63, pl. 15, fig. 11–13. CUSHMAN, 1946, U.S.G.S., Prof. Pap. 206, p. 129, pl. 53, fig. 24–31.

Test elongate, three to four times as long as broad, very gently tapering to blunt initial end, subcircular in end view, early portion biserial, becoming irregularly uniserial in adult; chambers rather indistinct in early portion, later distinct, inflated, and somewhat overlapping; sutures indistinct in early part, becoming distinct and much depressed, with pronounced reentrants and lobular projections; wall smooth and finely perforate in adult, with fine longitudinal costae in early portion; aperture terminal, oval.

*Dimensions.*—Length of hypotype .50 mm., breadth .17 mm.

*Remarks.*—This species is closely related to *Loxostomum clavatum* (Cushman), which in its typical form is more tapered, is biserial throughout, and shows stronger development of the sutural crenulations.

*Occurrence.*—This is a very common species in the Upper Cretaceous of America, occurring in the upper Austin chalk (Santonian) and Taylor formation (lower Campanian). It is common in the upper part of the Smokey Hill member of the Niobrara formation in Kansas, Nebraska, and South Dakota. It is rare in the sample from Redwood County, and the figured specimen is the only complete one found.

Family ROTALIIDAE Brady, 1884
Subfamily DISCORBISINAE Cushman, 1927
Genus GYROIDINA d'Orbigny, 1826
GYROIDINA sp.

Pl. 39, fig. 1a–c; Text-fig. 5—9a–c

Test small, trochoid, biconvex, more strongly so on ventral side, periphery sharply rounded; chambers indistinct, eight to ten in final whorl, increasing regularly in size as added, final one somewhat produced ventrally; sutures indistinct, faintly visible when specimen is moistened, slightly limbate, little if at all depressed, slightly curved; aperture not observed.

*Dimensions.*—Diameter of figured specimen .29 mm., thickness .15 mm.

*Remarks.*—This specimen is similar to *Gyroidina lenticulina* (Reuss), in size and shape, but that species has only five to six chambers in the final whorl. *Gyroidina nitida* (Reuss) is more globular, has a broadly rounded periphery, and fewer chambers in the final whorl. *Gyroidina depressa* (Alth) is not nearly so convex ventrally, has a more rounded periphery, and generally has more chambers in the final whorl.

*Occurrence.*—The illustrated specimen is from the "Sodergren Quarry," and is the only one representing this species.

Family GLOBIGERINIDAE Brady, 1884
Subfamily GLOBIGERININAE Cushman, 1927
Genus GLOBIGERINA d'Orbigny, 1826
GLOBIGERINA CRETACEA d'Orbigny

Pl. 39, fig. 4a–8b; 13a,b; 17

*Globigerina cretacea* D'ORBIGNY, 1840, Mem. Soc. Geol. France, ser. 1, vol. 4, p. 34, pl. 3, fig. 12-14

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EXPLANATION OF PLATE 37

All figures ×75

FIG. *1—Ammobaculites* sp. *1a*, side view, *1b*, peripheral view, Test Hole No. 19, 210 to 215 feet, Aitkin Co.

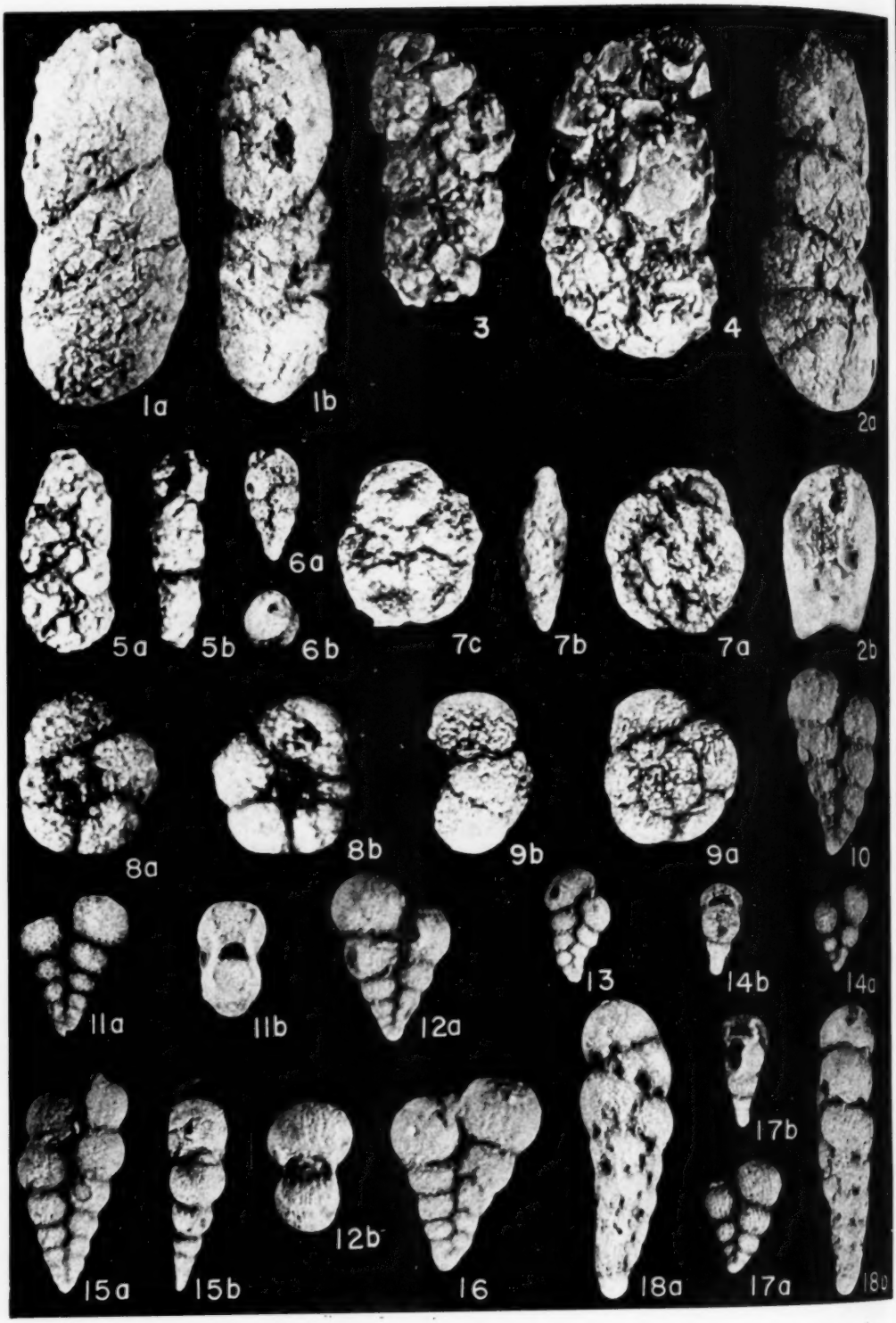
*2—Haplophragmoides* sp. *2a*, side view, *2b*, peripheral view, Test Hole No. 19, 252 to 257 feet, Aitkin Co.

*3–6—Haplophragmoides rudis* Bolin, n. sp. Test Hole No. 19, Aitkin Co. *3a*, side view, *3b*, peripheral view, 227 to 232 feet. *4a*, side view, *4b*, peripheral view, 292 to 297 feet. *5a*, side view, *5b*, peripheral view, 222 to 227 feet. *6*, side view, 222 to 227 feet.

*7–9—Haplophragmoides formosum* Bolin, n. sp. *7*, side view, Test Hole No. 1, 195 to 200 feet, Aitkin Co. *8a*, side view, *8b*, peripheral view, Test Hole No. 19, 232 to 237 feet, Aitkin Co. *9a*, side view, *9b*, peripheral view, Test Hole No. 7, 195 to 200 feet, Aitkin Co.

*10,11—Ammobaculites ovatus* Bolin, n. sp. Test Hole No. 19, Aitkin Co. *10a*, side view, *10b*, peripheral view, 277 to 282 feet. *11a*, side view, *11b*, peripheral view, 222 to 227 feet.

1a
1b
2b
2a
3a
3b
5b
4b
4a
6
7
8b
8a
5a
9b
10a
10b
9a
11b
11a


1a
1b
3
4
2a
5a
5b
6a
6b
7c
7b
7a
2b
8a
8b
9b
9a
10
11a
11b
12a
13
14b
14a
15a
15b
12b
16
18a
17b
17a
18b

MORROW, 1934, Jour. Paleontology, vol. 8, p. 198, pl. 30, fig. 7,8,10a,b. LOETTERLE, 1937, Nebraska Geol. Survey Bull., 2d ser., Bull. 12, p. 44, pl. 7, fig. 1,2. CUSHMAN, 1946, Cushman Lab. Foram. Research Contr., vol. 22, p. 17, pl. 3, fig. 5,6.

Test trochoid, with a slightly convex to flat spire of two and one-half to three whorls on dorsal side, and a large, deep, ventral umbilicus, periphery broadly rounded, strongly lobulate throughout; chambers distinct, nearly spherical but usually somewhat compressed, distinctly separated, increasing quite rapidly in size as added, usually six but sometimes five in final whorl; sutures distinct and strongly depressed throughout; surface covered with small spines which are more strongly developed on early chambers; aperture is large and arched, opening into umbilicus from final chamber, with a smooth, thickened lip.

*Dimensions.*—Greatest diameter of hypotype (Pl. 39, fig. 4) .42 mm., least diameter .38 mm., thickness .23 mm. Greatest diameter of hypotype (Pl. 39, fig. 5) .33 mm., least diameter .27 mm., thickness .19 mm. Greatest diameter of hypotype (Pl. 39, fig. 6) .34 mm., least diameter .30 mm., thickness .18 mm. Greatest diameter of hypotype (Pl. 39, fig. 7) .22 mm., least diameter .18 mm., thickness .12 mm. Greatest diameter of hypotype (Pl. 39, fig. 8) .40 mm., least diameter .35 mm., thickness .23 mm. Greatest diameter of hypotype (Pl. 39, fig. 13) .38 mm., least diameter .28 mm., thickness .20 mm. Greatest diameter of hypotype (Pl. 3, fig. 17) .33 mm., least diameter .28 mm., thickness .12 mm.

*Remarks.*—No other described species of this genus has such a large ventral umbilicus nor chambers as compressed as in most specimens of this species.

*Occurrence.*—This is a very common and widespread species in the Upper Cretaceous. It is fairly common in the sample from Lyon County, and abundant in that from Redwood County. Figures 4, 6, 8, and 17 (Pl. 3) are from the Redwood County sample, and figures 5, 7, and 13 (Pl. 3) from the Lyon County sample.

### GLOBIGERINA WASHITENSIS Carsey

Pl. 39, fig. 2a–3c; Text-fig. 5—11a,b

*Globigerina washitensis* CARSEY, 1926, Texas Univ., Bull., 2612, p. 44, pl. 7, fig. 10, pl. 8, fig. 2. PLUMMER, 1931, *idem.*, Bull. 3101, p. 193, pl. 13, fig. 12a,b.

Test compact, trochoid, with a very low to flat spire of two and one-half to three whorls on dorsal side, and a small, deep ventral umbilicus, periphery somewhat compressed, slightly lobulate; chambers distinct, globular but somewhat appressed, four in final whorl; sutures indistinct in early part, becoming distinct and slightly depressed in final whorl; surface with very coarse, polygonal perforations forming a

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### EXPLANATION OF PLATE 38

All figures ×75

FIG. *1,2—Ammobaculites elongatus* Bolin, n. sp. Test Hole No. 19, Aitkin Co. *1a*, side view, *1b*, peripheral view, 277 to 282 feet. *2a*, side view, *2b*, apertural view, 342 to 347 feet.

*3-5—Ammobaculoides* spp. Test Hole No. 19, Aitkin Co. *3,4*, side views, 292 to 297 feet. *5a*, side view, *5b*, peripheral view, 357 to 362 feet.

*6—Neobulimina* sp. *6a*, side view, *6b*, peripheral view, Sec. 7, T113N, R42W. Lyon Co.

*7—Trochammina minnesotensis* Bolin, n. sp. *7a*, dorsal view, *7b*, ventral view, *7c*, peripheral view, Test Hole No. 7, 240 to 245 feet, Aitkin Co.

*8,9—Trochammina globosa* Bolin, n. sp. Test Hole No. 19, Aitkin Co. *8a*, dorsal view, *8b*, ventral view, 317 to 322 feet. *9a*, dorsal view, *9b*, peripheral view, 252 to 257 feet.

*10,11,14,16—Gümbelina globulosa* (Ehrenberg). *10,16*, front views, "Sodergren Quarry," North Redwood, Redwood Co. *11,14*, Sec. 7, T113N, R42W, Lyon Co. *11a,11b*, front and apertural views, *14a,14b*, front and side views.

*12,17—Gümbelina* cf. *G. striata* (Ehrenberg). *12a,12b*, front and apertural views, "Sodergren Quarry," North Redwood, Redwood Co. *17a,17b*, front and side views, Sec. 7, T113N, R42W, Lyon Co.

*13—Gümbelina pseudotessera* Cushman. Side view, Sec. 7, T113N, R42W, Lyon Co.

*15—Gümbelina moremani* Cushman. *15a,15b*, front and side views, "Sodergren Quarry," North Redwood, Redwood Co.

*18—Loxostomum cushmani* Wickenden. *18a,18b*, front and side views, "Sodergren Quarry," North Redwood, Redwood Co.

honeycomblike pattern over entire test; aperture a high arched opening from final chamber into umbilicus.

*Dimensions.*—Greatest diameter of hypotype (Pl. 39, fig. 2) .27 mm., least diameter of .27 mm., and thickness of .20 mm. Greatest diameter of hypotype (Pl. 39, fig. 3) .30 mm., least diameter .24 mm., and thickness .20 mm.

*Remarks.*—The characteristic surface ornamentation distinguishes this species from all others of the genus.

*Occurrence.*—Only the two illustrated specimens were found in this material. The specimen shown in figure 2 (Pl. 39) is from test hole no. 7 at a depth of 230 to 235 feet, and that shown in figure 3 (Pl. 39) is from test hole no. 30 at a depth of 235 to 240 feet. The species has been recorded previously only in the Texas Lower Cretaceous (Washita and Fredicksburg). Its very rare occurrence here serves to extend its geographic and geologic range.

Genus GLOBIGERINELLA Cushman, 1927
GLOBIGERINELLA ASPERA (Ehrenberg)
Pl. 39, fig. 9a–11

*Planerostomum asperum* EHRENBERG, 1854, Microgeologie, pl. 30, fig. 26a,b, pl. 32, pt. 2, fig. 42.
*Globigerinella aspera* CUSHMAN, 1931, Tennessee Div. Geol., Bull. 41, p. 59, pl. 11, fig. 5a,b. LOETTERLE, 1937, Nebraska Geol. Survey Bull., 2d ser., Bull. 12, p. 45, pl. 7, fig. 4a,b. NAUSS, 1947, Jour. Paleontology, vol. 21, p. 337, pl. 48, fig. 9a,b.

Test small, planispirally coiled, somewhat evolute with parts of earlier coils visible on moistened specimens, nearly bilaterally symmetrical, subcircular in outline, periphery broadly rounded, strongly lobulate throughout; chambers distinct, strongly inflated, increasing uniformly in size as added, six or seven in final whorl; sutures distinct, strongly depressed throughout; wall finely perforate, spinose, more strongly so in early portion; aperture a high arched opening at base of final chamber, with a well developed lip.

*Dimensions.*—Greatest diameter of hypotype (Pl. 39, fig. 9) .23 mm., least diameter .20 mm., thickness .11 mm. Greatest diameter of hypotype (Pl. 39, fig. 10) .23 mm., least diameter .15 mm., thickness .09 mm. Greatest diameter of hypotype (Pl. 39, fig. 11) .18 mm., least diameter .15 mm., thickness .09 mm.

All figured specimens are from the Lyon County samples.

*Remarks.*—This species differs from *Globigerinella voluta* (White), in being more involute and in having the entire test more tightly coiled. In none of the specimens observed here was there any tendency toward a lengthening of the final chamber or chambers as is so common in many suites of the species.

*Occurrence.*—This is one of the more common species in the Upper Cretaceous of America, and was reported from the Niobrara formation of Kansas, Nebraska, and South Dakota by Loetterle. It is fairly common in the Lyon County sample and rare in the sample from the "Sodergren Quarry."

Family ANOMALINIDAE Cushman, 1927
Subfamily ANOMALININAE
Cushman, 1927
Genus ANOMALINA d'Orbigny, 1826
ANOMALINA sp.
Pl. 39, fig. 12a,b; Text-fig. 5—13a,b

Test rather small, planispirally coiled, at least in adult, nearly completely involute, almost bilaterally symmetrical, with a small, shallow umbilicus on each side, periphery rounded; chambers indistinct, triangular in shape, nine in final whorl; sutures indistinct, flush with surface, straight to very slightly curved; wall punctate; aperture an arched opening at base of final chamber, in the median line.

*Dimensions.*—Greatest diameter of hypotype .31 mm., least diameter .26 mm., thickness .16 mm.

*Remarks.*—This appears to be a new species, but was not given a specific designation. The broken figured specimen was the only one available for study.

*Occurrence.*—This specimen was found in the Lyon County sample.

Genus PLANULINA d'Orbigny, 1826
PLANULINA KANSASENSIS Morrow
Pl. 39, fig. 14–16; Text-fig. 5—10a,b; 14a,b

*Planulina kansasensis* MORROW, 1934, Jour. Paleontology, vol. 8, p. 201, pl. 3, fig. 2,15. LOETTERLE, 1937, Nebraska Geol. Survey Bull., 2d ser., Bull. 12, p. 49, pl. 8, fig. 2a–c. CUSHMAN, 1946, U.S.G.S., Prof. Pap. 206, p. 157, pl. 64, fig. 12a–c.

Test much compressed, dorsal and ventral sides nearly flat, somewhat trochoid, dorsal side completely evolute, showing two and one-half to three whorls, ventral side be-

coming somewhat involute in later part, central area of both sides usually covered with clear shell material, varying from a thin layer to a thick plug which may obscure early chambers, they become visible through plug when specimen is moistened however, periphery sharply rounded, slightly lobulate in later part; chambers distinct, numerous, eight to eleven in final whorl, increasing regularly in size as added; sutures somewhat indistinct in early portion, distinct and slightly depressed in later part, gently curved backward; wall quite coarsely perforate; aperture a low opening at base of final chamber, extending from periphery onto ventral side.

*Dimensions.*—Greatest diameter of hypotype (Pl. 39, fig. 14) .39 mm., least diameter .32 mm., thickness .12 mm. Greatest diameter of hypotype (Pl. 39, fig. 15) .36 mm., least diameter .30 mm., thickness .10 mm. Greatest diameter of small hypotype from Lyon County (Pl. 39, fig. 16) .23 mm., least diameter .20 mm., thickness .09 mm.

*Remarks.*—This species is similar to *Planulina taylorensis* Carsey, in some respects. However it is much smaller, is not as evolute ventrally, and lacks the keeled periphery and raised sutures of that species.

*Occurrence.*—The type of this species is from the basal Niobrara of Kansas. It occurs throughout the Niobrara of Kansas, Nebraska, and South Dakota, but is much more common in the lower (Fort Hays) member. In the Gulf Coast region it is most common in the lower Austin, with a few occurrences noted in the upper part. Three specimens of this species were found in the sample from the "Sodergren Quarry" (Pl. 39, figs. 14, 15), and a single small specimen (Pl. 39, fig. 16) from the Lyon County sample is also placed here. The latter may represent an immature specimen.

Subclass RADIOLARIA Müller, 1858
Order OSCULOSIDA Haeckel, 1887
Division CYRTELLARI Haeckel, 1882
Superfamily ARCHIPILLICAE Haeckel, 1882
Subsuperfamily SETHOPILILAE
Haeckel, 1882
Family LOPHOPHAENIDAE Haeckel, 1882
Subfamily LOPHOPHAENINAE Haeckel, 1882
Genus DICTYOCEPHALUS Ehrenberg, 1860
DICTYOCEPHALUS cf. D. MACROSTOMA Rust
Text-fig. 5—15

*Dictyocephalus macrostoma* RUST, 1892, Contrib. Can. Micropaleontology, Geol. Nat. Hist. Survey Canada, pt. 4, p. 106, pl. 15, fig. 1.

Rust described this species as follows:

> Shell thin-walled, smooth, without collar structure. Cephalis subspherical, hyaline, without pores. Thorax roundish urceolated with regular circular pores about as wide as the bars, in 15 to 16 oblique rows. Mouth less constricted than in the former species (*D. microstoma* Rust); two-thirds as wide as the thorax, without peristome.

*Dimensions.*—Length of hypotype .20 mm., breadth .15 mm.

*Remarks.*—This species is similar to *Dictyocephalus microstoma* Rust, but that species has the mouth only one-third as wide as the thorax and has 20 oblique rows of pores as compared to 15 or 16 in this species.

*Occurrence.*—The species was originally described by Rust from the lower Pierre shale of Manitoba, Canada. It is fairly common in the Lyon County sample.

Subsuperfamily TRIACARTILAE
Campbell, 1954
Family STICHOCORYTHIDAE
Haeckel, 1882
Subfamily STICHOCORYTHINAE
Haeckel, 1882
Genus DICTYOMITRA Zittel, 1876
DICTYOMITRA sp.
Pl. 39, fig. 20

Shell small, conical, slightly asymmetrical, consisting of five joints separated by quite broad horizontal septal bands which are but little indented; terminal joint widely open; surface of shell covered with small circular pores in irregular longitudinal rows, three to four pores per row in each joint.

*Dimensions.*—Length of hypotype .20 mm., breadth .12 mm.

*Remarks.*—The specimen figured here appears to represent a new species lacking as deeply indented strictures between joints as other species of this genus, and with more irregular surface ornamentation.

*Occurrence.*—A single shell was found in the Lyon County sample.

Subgenus DICTYOMITRA
Haeckel, 1887
DICTYOMITRA (D.) cf. D. (D.)
MULTICOSTATA Zittel
Pl. 39, fig. 19

*Dictyomitra multicostata* ZITTEL, 1876, Zeit. deutsch geol. Gesell., vol. 28, p. 81, pl. 2, fig. 2–4. RUST, 1892, Contrib. Can. Micropaleontology, Geol. Nat. Hist. Survey Canada, pt. 4,

p. 109, pl. 16, fig. 3. NAUSS, 1947, Jour. Paleontology, vol. 21, p. 341, pl. 48, fig. 3, 8.
*Dictyomitra* (*Dictyomitroma*) *multicostata* CAMPBELL & CLARK, 1944, Geol. Soc. Am., Spec. Pap. no. 57, p. 39, pl. 8, fig. 22–24,29,35,42.
*Dictyomitra* (*Dictyomitra*) *multicostata* CAMPBELL, 1954, Treatise on Invertebrate Paleontology, Part D, Protista 3, p. D140, Fig. 72, 2.

A single specimen from the Lyon County sample is referred to this species, which was described as follows by Rust:

> Shell slender conical with prominant longitudinal ribs, and from eight to ten deep strictures. Length and breadth of the joints gradually increasing, the eighth joint being twice as long and broad as the fourth joint. Pores regular circular, one series in each longitudinal furrow, three to four pores in each joint.

*Remarks.*—The specimen referred here (Pl. 39, fig. 19) consists of nine joints and is .22 mm. long and .13 mm. broad. It lacks the deep strictures between the joints shown by this species, but agrees very well in other characteristics. It has the prominent longitudinal costae with one series of three or four pores in each furrow, and corresponds in size and shape. *Dictyomitra* (*D.*) *tiara* var. *aspinosa* Campbell & Clark has fewer joints, and has six pores per joint in each longitudinal furrow.

*Occurrence.*—This species has been reported previously in North America from Canada and California. Rust found it in the lower Pierre shale of Manitoba, and Nauss recorded it in the upper Lloydmaster shale and lower Lea Park shale (Cenomanian) of Alberta. Campbell & Clark found it in the Corral Hollow shale (probably Upper Senonian) of California.

Order OSTRACODA Latreille, 1806
Family CYTHERIDAE Baird, 1850
Genus CYTHEREIS Jones, 1849
CYTHEREIS aff. C. QUADRIALIRA Swain
Pl. 39, fig. 18a–c

*Cythereis quadrialira* SWAIN, 1952, U.S.G.S., Prof. Pap. 234-B, pt. 2, p. 84, pl. 9, fig. 27–30.

Carapace subquadrate-acuminate in side view, highest about one-quarter of length from anterior end; anterior margin broadly and evenly rounded, finely denticulate along lower two-thirds, with a finely spinose marginal ridge which terminates just below antero-dorsal junctufe in a rounded eye tubercle; posterior end roundly triangular in shape, with scattered small spines both above and below angulation, and slightly thickened marginal rim; dorsal margin nearly straight, ventral somewhat sinuous, subparallel to dorsal; valve convex, thickest about one-quarter of length from posterior end, anterior and posterior ends much compressed. Surface with four distinct ridges; first extends along ventral margin, beginning one-quarter of length from posterior end and dying out one-third of length from anterior end; just dorsal of this, a second longitudinal ridge extends from anterior marginal ridge, parallels ventral margin to point two-fifths of length from anterior margin, then angles slightly upward and ends at a small node one-fifth of length from posterior end, with a row of coarse perforations along dorsal margin, and crenulations along ventral margin of angled portion of ridge; a prominent, slightly arcuate median ridge extends from a small irregular node one-fifth of length from posterior end to an oval node one-fifth of length from anterior end, this ridge is expanded and node-like just anterior to middle, other smaller expanded areas occur at irregular intervals, anterior node bears a diagonal row of three small perforations; a thick, somewhat crenulate ridge extends forward from post-dorsal juncture, arches slightly downward and dies out just beneath eye tubercle.

Hinge line slightly curved, about two-thirds of length of shell. Hinge structure of right value consists of terminal teeth, a small rounded socket postjacent to anterior tooth, and a narrow groove extending from socket to posterior tooth. Muscle scars and inner margin not observed.

*Dimensions.*—Length of hypotype .67 mm., height .37 mm., thickness of right valve .19 mm.

*Remarks.*—This specimen differs only slightly from *Cythereis quadrialira* Swain, described from beds of Eutaw? age from Dare County, North Carolina. The ornamental features, with only slight variations, are all shown by this specimen. The major difference is the more strongly convex shell of the specimen described here. *Cythereis niobrarensis* Morrow, is similar in size and shape, but differs greatly in surface ornamentation.

*Occurrence.*—The figured right valve is from the "Sodergren Quarry," and is the only ostracode specimen from this material.

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## EXPLANATION OF PLATE 39

All figures ×75

FIG. *1*—*Gyroidina* sp. *1a*, dorsal view, *1b*, ventral view, *1c*, peripheral view, "Sodergren Quarry," North Redwood, Redwood Co.

*2,3*—*Globigerina washitensis* Carsey. *2a,2b*, dorsal and ventral views, Test Hole No. 7, 230 to 235 feet, Aitkin Co. *3a*, dorsal view, *3b*, ventral view, *3c*, peripheral view, Test Hole No. 30, 235 to 240 feet, Crow Wing Co.

*4–8,13,17*—*Globigerina cretacea* d'Orbigny. *4,6,8,17*, from "Sodergren Quarry," North Redwood, Redwood Co. *4a,4b*, dorsal and peripheral views; *6a,6b*, dorsal and ventral views; *8a,8b*, dorsal and peripheral views; *17*, dorsal view; *5,7,13*, from Sec. 7, T113N, R42W, Lyon Co. *5*, ventral view; *7*, dorsal view; *13a,13b*, dorsal and peripheral views.

*9–11*—*Globigerinella aspera* Ehrenberg. Sec. 7, T113N, R42W, Lyon Co. *9a,9b*, side and peripheral views; *10,11*, side views.

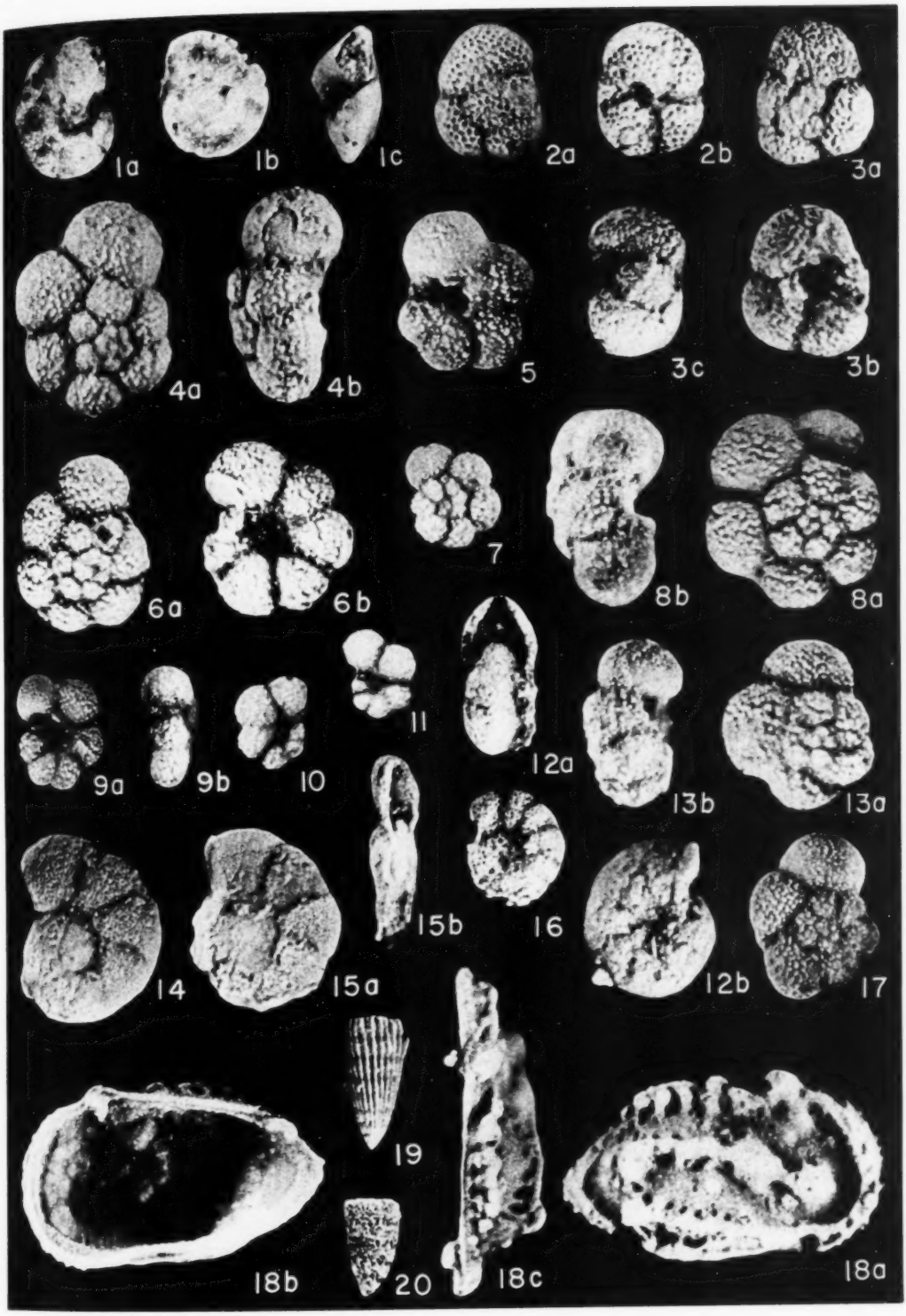
*12*—*Anomalina* sp. *12a,12b*, dorsal and peripheral views, Sec. 7, T113N, R42W, Lyon Co.

*14–16*—*Planulina kansasensis* Morrow. 14,15, from "Sodergren Quarry," North Redwood, Redwood Co. *14*, ventral view; *15a,15b*, ventral and peripheral views; *16*, dorsal view, Sec. 7, T113N, R42W, Lyon Co.

*18*—*Cythereis* aff. *C. quadrialira* Swain. *18a*, side view of right valve, *18b*, interior view, *18c*, dorsal view, "Sodergren Quarry," North Redwood, Redwood Co.

*19*—*Dictyomitra* (*D.*) cf. *D.* (*D.*) *multicostata* Zittel. Sec. 7, T113N, R42W, Lyon Co.

*20*—*Dictyomitra* sp. Sec. 7, T113N, R42W, Lyon Co.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Francis G. Stehli
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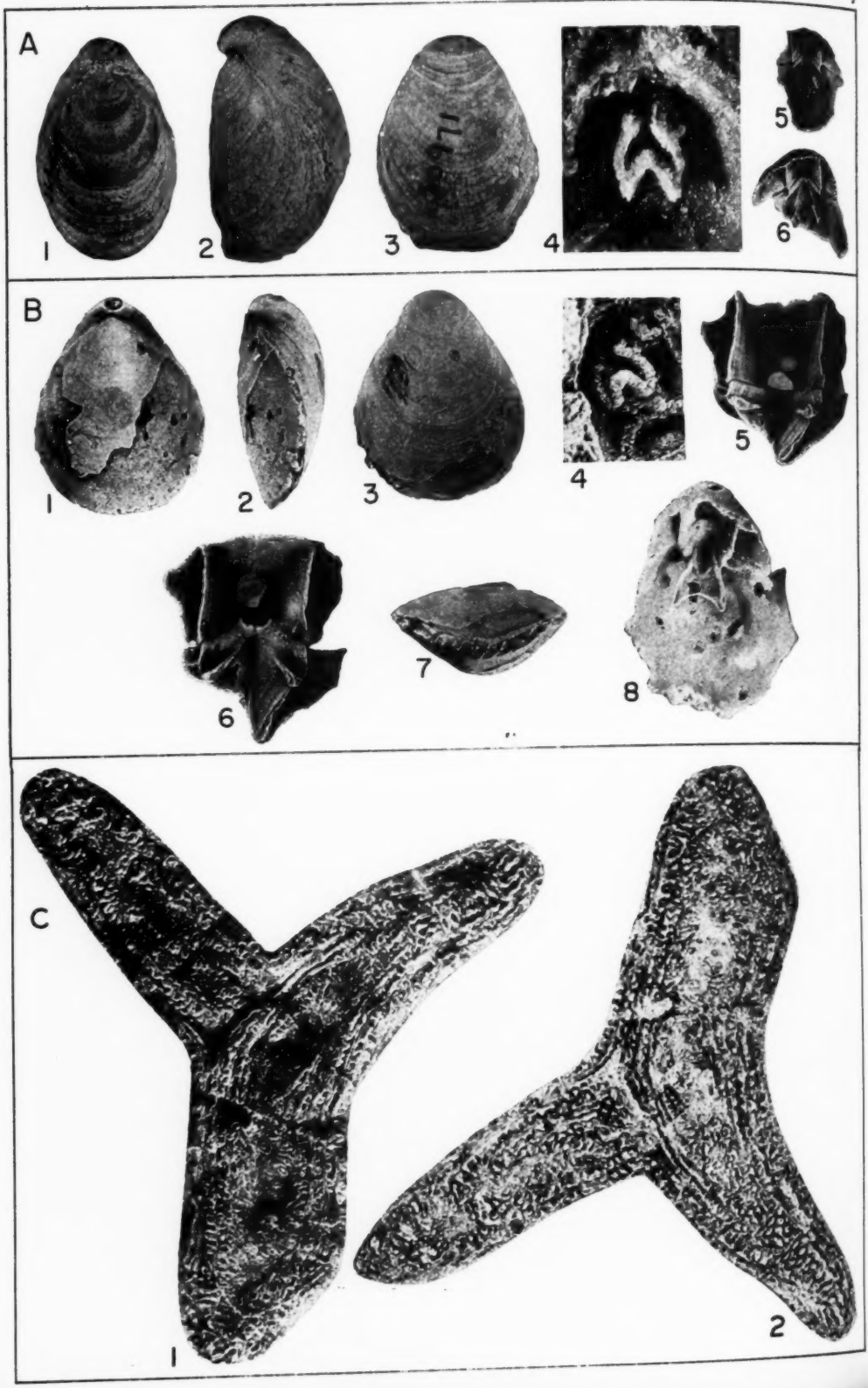

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 2, P. 299–302, PL. 40 A, B, 2 TEXT-FIG., MARCH 1956

# *DIELASMA* AND ITS EXTERNAL HOMEOMORPH *BEECHERIA**

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ABSTRACT—Two externally homeomorphous genera have been found to be included in "*Dielasma*" of authors (*non* King 1859). Ambiguity was introduced into the generic concept early and eventually resulted in general acceptance of a generic diagnosis which excluded the genotype. *Dielasma* is here restricted to those species showing the essential characters of the genotype and is considered to be a senior synonym of *Dielasmoides* Weller, 1914. A neotype is designated for *Terebratulites elongatus* Schlotheim to replace the original type material destroyed in the war. The name *Beecheria* is revived for external homeomorphs of *Dielasma* having the internal characters of *Beecheria davidsoni* Hall & Clarke.

## INTRODUCTION

AMONG Upper Paleozoic Terebratuloidea perhaps no genus is more familiar to paleontologists and stratigraphers than *Dielasma*. The name has been widely applied throughout the world. In many cases the generic assignment may be correct, but the name has been commonly used to include two external homeomorphs of quite different internal structure. In the hope that the confusion surrounding *Dielasma* could be reduced, the genus has been subjected to careful study.

An attempt was made to obtain the type material of *Terebratulites elongatus* Schlotheim, the genotype of *Dielasma*. The writer has received letters from both Dr. O. H. Schindewolf, formerly at the Geologisch-Paläontologisches Institut und Museum, Berlin, the repository for the types, and from Dr. Kurt Diebel, the present Curator, to the effect that the material was destroyed during the last war. The original material described by Schlotheim seems to have come from the Hohlenkalkstein near Glucksbrunnen and Liebenstein in the vicinity of Coberg, Thuringia. This region is now under Russian control, and it has proved impossible to get material from Schlotheim's localities. A considerable amount of material has been obtained which came from the vicinity of Pössneck, Thuringia, and from the same horizon as the types. These specimens are all very similar and agree well with the rather crude figures of Schlotheim (1816, Pl. 7, fig.

* California Institute of Technology, Division of the Geological Sciences, Contribution No. 762.

## EXPLANATION OF PLATE 40

A. *Beecheria*

FIG. *1-3*—*B. bovidens* (Morton). Brachial, profile and pedicle views of a specimen from the "Coal Measures," Kansas City, Mo., showing the external form most commonly seen in this genus; ×1½.

*4*—*B. davidsoni* Hall & Clarke, from the Windsor series of Nova Scotia showing the somewhat encrusted, short terebratulacean loop.

*5,6*—*B.* sp., from middle Missourian strata in Grapevine Canyon, New Mexico. Silicified and etched specimens showing the characteristic cardinalia of the genus.

B. *Dielasma*

FIG. *1-3,7*—*D. elongatum* Schlotheim. Brachial, profile, pedicle and interior views of the neotype from Pössneck, Thuringia, Germany showing the characteristic external form of this species.

*4*—Encrusted loop of *D. elongatum* from Pössneck.

*5,6*—*D.* sp. Silicified and etched specimen from the Middle Permian of Texas showing the cardinalia characteristic of the genus.

*8*—*D.* sp. Silicified specimen from the Middle Permian of Texas showing a perfect loop.

C. *Parafusulina*

FIG. *1,2*—*P. maleyi* Dunbar & Skinner. Acetate peel of teratoid specimen under (*1*) reflected and (*2*) transmitted light, ×7.

7–9). These specimens have been carefully studied with regard to both external and internal characters, and one has been selected as the neotype of *Terebratulites elongatus* Schlotheim. The neotype together with supplementary material has been presented to the U. S. National Museum where it may be found under the number 124226 in the collections of fossil invertebrates.

A history of the generic assignments given in the literature to *Terebratulites elongatus* Schlotheim, is long and complex. In order to resolve the nomenclatorial problems attending the use of the name *Dielasma*, it is considered necessary, however, to give a brief résumé of usage. The name *Terebratulites elongatus* was proposed by Schlotheim (1816, p. 27) for a species from the Upper Permian Zechstein dolomite (Hohlenkalkstein) of Thuringia, Germany. Schlotheim (1823) later changed his usage of the name and included in *T. elongatus* forms as old as Devonian, which are now known to be generically distinct. He used at this time the name *T. subelongata* for the Zechstein form. Geinitz (1861, p. 82) has correctly noted that this was improper and that the correct usage was that of Schlotheim, 1816.

King (1850) in treating the Permian fossils of England, selected *Terebratulites elongatus* Schlotheim as typical of a group which he wished to distinguish from *Terebratula*. He did not, however, give a name to this group but used the name *Epithyris* Phillips. Buckman (1906) has pointed out that the genus *Epithyris* was established by Phillips (1841) for *Terebratula maxilata* Sowerby, a Jurassic species. The internal characters of *T. maxilata* have apparently never been investigated, but it is certainly generically distinct from *Terebratulites elongatus*. The name *Epithyris* was thus not available for use by King in connection with the Zechstein species. King (1859) realized this and proposed instead the name *Dielasma* for *Terebratulites elongatus* and congeneric species.

Schlotheim (1816) presented figures of the exterior of *T. elongatus* which, though very crude, show its general characters. King, at the time of his first recognition of *T. elongatus* as belonging to a generic group distinct from *Terebratula*, presented figures showing the critical internal structures (King, 1850, pl. 6, fig. 45). Davidson (1858) later figured additional interiors. Hall & Clarke (1894, p. 295) first introduced ambiguity in their diagnosis of *Dielasma*. They apparently relied for internal details on such species as *Terebratula bovidens* Morton with which they were familiar, but which do not belong to *Dielasma*. Though they reproduced at the same time a text-figure from Davidson (1858) which correctly showed the internal features, they evidently misinterpreted it. Weller (1914) followed Hall & Clarke in their interpretation of *Dielasma*, but refined their concept by excluding from the genus all forms not showing the internal characters of *Terebratula bovidens* Morton. He thus excluded from the genus, forms with the internal structure of the genotype. This was in part due to his misinterpretation of an internal mold and an interior of *Terebratulites elongatus* figured by Davidson (1858, pl. 1, fig. 18, 20). Weller believed that the area marked by the letter O in Davidson's figure 18 represented the median part of the cardinalia of a *Terebratula bovidens* type of structure. In reality, it represents the site of muscular insertion on the floor of the valve between the parts of the divided cardinal plate of true *Dielasma*. Forms having the internal structure of *Terebratulites elongatus* were placed by Weller (op. cit.) in a new genus *Dielasmoides*. The usage of *Dielasma* given by Weller was employed by most subsequent workers. Cloud (1942, p. 113) suggested that "*Dielasma*" of authors was probably polyphyletic, and Stehli (1954, p. 353) has pointed out that current usage is improper. *Dielasma* is here restricted to those species showing the internal and external characters of *Terebratulites elongatus* Schlotheim.

The name *Beecheria*, proposed by Hall & Clarke (1893) with *Beecheria davidsoni* as genotype, is revived to include a group of external homeomorphs of *Dielasma*. While clearly indicating *Beecheria davidsoni* from the Mississippian Windsor group of Nova Scotia, Canada, as the genotype, Hall & Clarke apparently drew their generic diagnosis largely from *Hemiptychina sublaevis* which they erroneously believed to be congeneric. Bell (1929) in an excellent study of the fauna of the Windsor group recognized that *B. davidsoni* possessed exactly the in-

ternal characters then believed to be present in *Dielasma*. He therefore recommended supression of the name *Beecheria* in favor of *Dielasma*. It is now clear that the type of interior found in *Dielasma* s.s. is quite unlike that of *Beecheria* and the latter name is necessary to include members of this externally homeomorphous series.

### Genus DIELASMA King, 1859

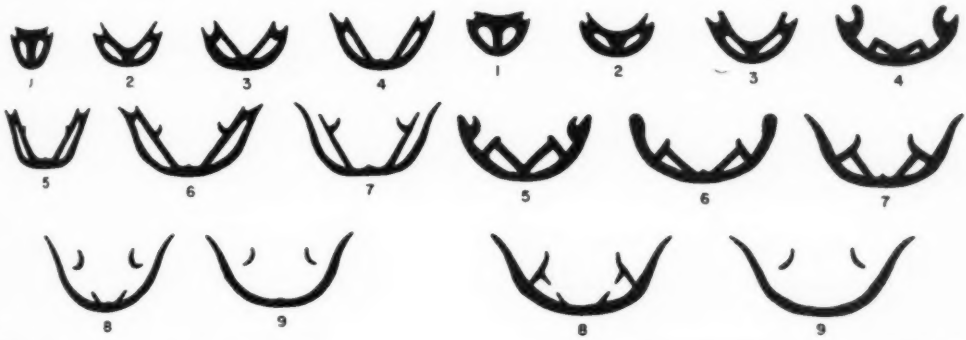
*Discussion.*—As noted above, Weller (1914), in defining *Dielasma*, excluded from the genus representatives of *Dielasma* s.s. In his Mississippian material a single species, *Dielasmoides bisinuata*, was found which showed the internal characters of *Dielasma*, and for it he proposed a new genus. According to Weller (op. cit., p. 255), all adults of *Dielasmoides bisinuata* probably show an anterior commissure which is to some degree sulciplicate. Adult topotype specimens of this species examined by the writer more often show a uniplicate than a sulciplicate anterior commissure, and a complete range is present between the two types of commissure. It is concluded that modification of the anterior is not, in this case, a valid specific character. It is certainly not a character of generic significance and, as it is the only known feature in which *Dielasmoides* differs from *Dielasma*, the name *Dielasmoides* is rejected as a junior synonym of *Dielasma*.

*Dielasma* appears to have evolved from *Cranaena* by way of *Hamburgia* in the late Devonian or early Mississippian. *Dielasma* s.s. is first known from the Meramecian (St. Louis ls.) of the Mississippi Valley. The genus is rare in the Pennsylvanian but becomes dominant in the Permian. Generically distinct derivatives continue at least into the Triassic.

### DIELASMA ELONGATUM (Schlotheim)
Pl. 40, fig. B 1–4,7

*Diagnosis.*—Moderate sized *Dielasma* of oval outline, subequally convex longitudinal cross section and unequally convex transverse section. Pedicle valve of moderate longitudinal convexity, most convex near the beak and becoming less so anteriorly; transversely convex near the beak but flat to slightly concave anteriorly due to the development of a shallow sulcus; pedicle beak erect; beak ridges rounded; deltidial plates conjunct; pedicle foramen permesothyrid, marginate to labiate. Brachial valve longitudinally of even but low convexity; transversely of high convexity due to an indistinct fold. Anterior commissure mildly uniplicate; later commissure sinuate, convex toward the pedicle valve. Color pattern unknown.

Pedicle interior with well developed dental plates and a short pedicle collar; muscle insertions unknown but probably as in other species. Brachial interior with a small and imperfectly developed cardinal process or diductor muscle attachment site apically. Cardinal plate divided into two discrete plates each running from the socket plate to the valve floor without other attachment; one crus arising from each part of the cardinal plates; crural points normal; loop short and centronelliform in early ontogeny, but reaching a dielasmoid form in adults; trans-




TEXT-FIG. 1—Diagrammatic serial sections of the brachial valve of *Dielasma*.




TEXT-FIG. 2—Diagrammatic serial sections through the brachial valve of *Beecheria*.

verse band moderately recurved; position of muscle insertions uncertain but probably as in other species of the genus.

*Discussion.*—The above description is drawn from serial sections and from internal structures preserved in hollow shells from Pössneck, Thuringia, Germany. It is not entirely in agreement with the description of the genotype given by King (1859, p. 260) in which he states " . . . umbonal cavity of the small valve furnished with muscular fulcral plates, oblique, confluent, and forming a sternum-like process, supported by a medio-longitudinal plate." No such development has been noted in *Dielasma elongatum* by the writer, but it has been seen in some individuals from the Permian of Texas, and apparently falls within the range of normal individual variation.

### Genus BEECHERIA Hall & Clarke, 1893
Pl. 40, fig. A 1–6

Genotype: *Beecheria davidsoni* Hall & Clarke, 1893, Paleontology of New York, vol. 8, pt. 2, p. 300, fig. 224–225.

*Diagnosis.*—Lower Mississippian to Middle Permian external homeomorphs of *Dielasma;* pedicle interior as in *Dielasma;* brachial interior with the cardinal plate medially sessile and divided into two discrete plates laterally supported by crural plates; cardinal plate obsolete between crural plates and socket plates; loop dielasmoid, transverse band moderately recurved.

*Discussion.*—*Beecheria* belongs to a stock which became completely distinct from that which produced *Dielasma* at least as early as the Upper Devonian (Chemung). An ancestral form, as yet undescribed, has been found, in the Upper Devonian of New York State, in which the cardinal plate has not yet become medially sessile or divided. Similarity of the loop and the internal and external features of the pedicle beak indicate that both *Dielasma* and *Beecheria* probably originate in the Cranaeninae.

*Beecheria* is abundant in the Mississippian and Pennsylvanian. It occurs rarely in the Lower and Middle Permian but thereafter disappears, though specialized and generically distinct derivatives continue at least through the remainder of the Paleozoic.

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JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 2, P. 303–304, PL. 40 C, MARCH 1956

# A TERATOID *PARAFUSULINA*

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ABSTRACT—An abnormal specimen of *P. maleyi* Dunbar & Skinner is illustrated and described. It is believed to be from the Permian Getaway limestone of the Guadalupe Mountains, West Texas.

IN 1950, during the field investigations of the Newell party[1] in the Guadalupe Mountains, a strange Y-shaped representative of *Parafusulina* was found in the rubble of one wall of the Pinery. The Pinery is the ruin of a military post on the old Butterfield trail at the foot of Guadalupe Peak, near Pine Spring, Texas. The fusulinid (Pl. 43, fig. C1, 2) is weathered to a near-axial section at the limestone cobble surface, and the proloculum is visible. The Y-shape is due to fracture and regeneration at the fractured end. The cobble is evidently from the middle Guadalupian (Permian) Getaway limestone, which outcrops within 300 yards of the ruin (King, 1948, pl. 3). The limestone is a dark gray calcilutite. Normal representatives of *Parafusulina maleyi* occur in the cobble, and it is believed that the teratological specimen is also of that species, although another species of *Parafusulina* of similar dimension (*P. rothi*) is also known from the Getaway limestone.

The teratoid specimen (Am. Mus. Nat. Hist., 27948) has a normal proloculum and three complete volutions that were developed before fracture. The fourth volution is incomplete, evidently fractured. The fifth volution is obscured but may have been fractured. The sixth, seventh, and eighth volutions are complete around the entire Y-shaped shell.

[1] From 1948 to 1952 Dr. Norman D. Newell of the American Museum of Natural History and Columbia University directed a study of the Permian reef complex in the Guadalupe Mountains of West Texas and New Mexico. The major results of that project were published by Newell et al., 1953.

Dunbar & Skinner (1937) noted teratism in their specimens of *P. rothi*. They state (p. 685):

> Among these elongated shells are found remarkable instances of injury and repair. The specimen shown as figure 12 of Plate 76 had been 12 and 13 volutions when it was broken in two only 4 mm. from the proloculum. The larger portion lived and the last two volutions grew over the broken end, completely patching it. Another shell of the same species in the authors' collection shows that the short end of such a broken shell, even though it lacked a proloculum, could regenerate the missing part. This specimen starts with a nucleus which is a fragment of the end of a shell only 1.1 mm. in diameter and 1.2 mm. long. Nine volutions were added after the injury and the broken end was regenerated until it is almost as long as the other.

Concerning *P. maleyi*, they note (p. 687):

> This species is associated with *P. rothi* which it closely resembles in many respects. A separation is based chiefly upon shape and proportions, *P. rothi* being thicker at corresponding volutions and shorter and more stubby at maturity.

Further study of terata may furnish a key for morphological and ecological studies. For instance, from Dunbar & Skinner's (1937) description of the fusulinid fragment without a proloculum regenerating itself to near normal proportions, the assumption of multiple nuclei might be drawn. Also, terata with multiple proloculi are known from many species (Thompson, 1948, p. 10). Further study of prolocular and tunnel structures may lead to conclusions as to the number and location of nuclei within the organism. It might also be found that only the "higher" forms (*Parafusulina*, *Poly-*

*diexodina*) can regenerate without the proloculum.

It is neither plausible to attempt specifically to collect teratoid specimens, nor to re-examine all existing collections. However, notation by many observers over a period of years may divulge the significance of teratology in the study of paleoecology.

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JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 2, P. 305–313, PL. 41, 42, 1 TEXT-FIG., MARCH 1956

# NOTES ON OLDHAMINID BRACHIOPODS*

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ABSTRACT—The aberrant brachiopod genera included in the family Oldhaminidae possess a peculiar brachial valve which has been thought to be an immobile internal plate. Detailed study of excellently preserved material suggests that the brachial valve was functional and served for protection and lophophore support. A ptycholophus lophophore was characteristic of the family and incurrent waters probably entered the shell via the distal ends of the lateral lobes while excurrent waters left it via the median incision. Two groups, one characterized by symmetrical and the other by asymmetrical musculature may be distinguished and do not coincide with the groups previously separated on the basis of symmetry or asymmetry of the brachial valve. Two new genera *Rigbyella* and *Pseudoleptodus* are described. A new species is questionably referred to *Adriana*. The Triassic genus *Pterophloios* is figured and discussed and is referred to the Oldhaminidae. Such ecologic data as exist are presented for each of the species considered.

## INTRODUCTION

Not uncommonly, an aberrant group arouses more interest and receives more study than is accorded important but commonplace relatives, and yet remains imperfectly understood. Among Upper Paleozoic brachiopods this has been the case with the unusual and highly specialized oldhaminids, for though they have received a disproportionately large amount of study they are still poorly known. Many investigations of the group have been based on imperfect material as witnessed by the fact that various representatives were placed first as fish and later as gastropods prior to their recognition as brachiopods. Recent studies of silicified Permian faunas from the Guadalupe Mountains of West Texas, based on nearly perfect specimens, have added many details to our knowledge of the group and so justify further discussion.

Many of the specimens examined reveal evidence of the nature and position of the soft parts, and this makes possible what are at least probable reconstructions of some gross aspects of the soft anatomy. Recovery of many specimens either in position of growth or clearly showing attachment scars permits some conclusions as to living habits. Good control on Permian water depth is possible in the collecting area and some indication of habitat preferences can be gained.

Since Waagen's (1882) recognition of the oldhaminids as brachiopods, important studies of the group have been made by Noetling (1905), Watson (1917), Fredericks (1926), Wanner & Sieverts (1935) and by Williams (1953). The recent study by Williams is a comprehensive one which includes discussion of the shell structure, gross morphology and classification. He presents the arresting and original idea that the brachial valve in this group was an internal plate and the animal functionally univalved. It was in part to test this hypothesis that the present investigation was undertaken, and evidence bearing on this point is set forth below.

*The brachial valve and associated structures.*—The brachial valve in advanced oldhaminids is a highly complex structure which in outline more nearly resembles a fern frond than the typical brachiopod valve. It generally consists of a more or less massive posterior plate from which two main trunks, often posteriorly united, run forward giving off lateral branches. It has been shown by Williams (1953) that with the exception of a very small triangular area near the hinge the valve consists of only a single shell layer. This was determined by the study of sections but is also apparent from observation of the shell surface which exhibits numerous pseudopunctae (a feature of the inner shell layer of typical strophomenids) except in a small triangular area near the hinge, where they are hidden by the lamellar layer.

In Recent terebratuloid brachiopods Wil-

* California Institute of Technology, Division of the Geological Sciences, Contribution No. 763.

liams has observed that the inner shell layer is secreted only by the surface of the mantle and that internal structures composed only of the inner layer are formed in invaginations of the mantle. From this evidence he reasons that the brachial valve of the oldhaminids, consisting almost exclusively of this shell layer, must have been internal.

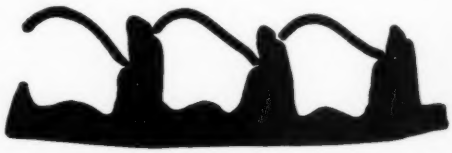
The unusual shape of the brachial valve has excited the curiosity of many investigators and has evoked much speculation. If viewed in other than functional morphologic terms, its shape seems inexplicable. So considered, however, it becomes apparent that the peculiar shape must bear an intimate relationship to the lophophore. In all Recent articulate brachiopods the lophophore occupies most of the area between the valves while the remaining viscera are limited to a small posterior space. Fossil articulates giving evidence on this point also suggest that the lophophore generally occupied not only the anterior portions of the valves, but a majority of the enclosed space. It seems beyond doubt that a similar situation existed in the oldhaminids.

One of the prime functions of the brachial valve is the support of the lophophore and reduction of the valve may logically be supposed never to have proceeded to such a stage that efficiency as a lophophore support was lessened. This being the case, and the oldhaminid brachial valve being as drastically reduced as it is, it seems probable that its shape was closely related to that of the lophophore itself. A careful examination of the interior of the brachial valve in well preserved specimens reveals a slight ridge close to and paralleling the margin throughout the extent of the valve (Pl. 41, fig. 3). This ridge was probably the site of attachment of what can only have been a complexly ptycholophus lophophore.

Recent work on the feeding mechanisms of brachiopods by Richards (1952) suggests that feeding is accomplished by the forcing, under differential pressure, of the food bearing water currents past the filaments of the lophophore. Unfortunately, the observations leading to this conclusion were limited to one species, with a plectolophus lophophore, and were not complete. Such mechanical data as are now available indicate that the probable distribution of currents was as Williams (1953, p. 284) has suggested, with incurrent waters entering the distal ends of the lateral lobes and excurrent waters leaving by way of the median incision. However, until a comprehensive study of the water current system of some living ptycholophus form such as *Lacazella* is carried out, it is impossible to do more than speculate about water currents in the oldhaminids.

Interpretation of the morphology and function of the oldhaminids depends considerably on the nature of the brachial valve. If, as Williams contends, the valve was an immobile internal plate, then function must be analyzed within the rather narrow parameters possible in such an animal. If, on the other hand the brachial valve was functional, the animals were less specialized than Williams suggests, and more like normal brachiopods. It is necessary therefore at this point to investigate evidence bearing on the function of the brachial valve.

The oldhaminid hinge is very short and in this respect quite unlike that of most related groups. Despite this peculiarity, the brachial valve rests freely in the articular area of the pedicle valve and was, when normally developed, structurally capable of considerable movement. Striated surfaces of the pedicle articular area suggest movement. The articulation is somewhat different in principle from that in most strophomenids for the two valves were not in contact throughout the extent of a long hinge but at two points only, one on either side of the hinge. This system had the advantage of continuously increasing the leverage of the diductor muscles as the valves became longer and heavier, for the point of articulation continued to migrate upward with growth. If the brachial valve were an immobile, internal plate such an adaption seems in-



TEXT-FIG. 1—Longitudinal section of part of an oldhaminid shell showing the relationships of the brachial valve to the pedicle valve and the seating notches in the latter in which the brachial valve snuggly fits.

explicable as does the persistence of articulation itself.

Interpretation and even discovery of the muscle patterns in oldhaminids is often difficult because poor impression of the scars seems to be the rule. A careful examination of a large number of specimens and most published illustrations indicates that the group is divisible into two large sections on the basis of the muscle pattern. One group retains the essentially symmetrical musculature characteristic of brachiopods in general. The other possesses a peculiar and highly specialized asymmetrical musculature.

In the first group the musculature is basically symmetrical although individual variation due to asymmetry of the shell as a result of crowding or peculiarities of the attachment surface is high. The muscle pattern is fairly well known for at least some members of this group. *Coscinophora* Cooper & Stehli may be cited as an example. In the pedicle valve a pair of large elongate, medially located adductors are bordered by the much smaller, elongate diductors—such a size relationship is unlike that of other brachiopod groups, and the extreme development of the adductors was probably necessitated by the difficulties of holding a valve of such large surface area in place in agitated water. In the brachial valve the cardinal process is reduced in the fashion characteristic for oldhaminids. This was apparently required by the extreme shallowness of the body chamber and was not, as Williams implies (1953, p. 284), due to degeneracy. The feature can be seen, in well preserved specimens, to bear distinct scars for diductor attachment. Anterior to the cardinal process are the insertions of adductors, which can be seen only on exceptional material and then, poorly. If the size of the muscle scars is any indication of functionality, as indeed it must be, then the musculature of these animals was functional and not as Williams suggests "degenerate to a degree of almost total atrophy." It is interesting that *Coscinophora* which possesses well developed muscle scars also had a massive, brachial valve. This may account for their strong impression in this genus as contrasted to the weak impression in most others.

Among the asymmetrically muscled group of oldhaminids, impression of muscle scars is very poor. Typically, only the very large right diductor muscle (interpretation of this large right muscle as having a diductor rather than adductor function as supposed by Watson (1917) is discussed under the description of *Adriana? guadalupensis*) scar can be noted, and this only because it was characteristically housed in a more or less calcified sheath. Such other muscle impressions as we have observed are discussed by Watson (1917) in his description of *Poikilosakos*. In this genus the brachial interior, insofar as the writer is aware, is almost completely unknown. In spite of very incomplete knowledge, it is apparent that the right diductor at least was large and presumably functional.

In summary, it may be said of such oldhaminids as preserve well impressed muscle scars, that the musculature is well developed and presumably powerful. As this is the case where the evidence is clear, it seems unnecessary to assume atrophy in those forms in which muscular impression is poor or in which the details of the musculature are simply unknown. The presence of well developed muscles seems to indicate that they were functional. Functional adductor and diductor muscles can only mean mobility of the brachial valve, unless the muscles had become modified to serve some other purpose, and of this there is no evidence whatever.

Williams believed that the oldhaminids could not move the brachial valve and suggests that this immobility was not detrimental to the animal. He suggests further that the brachial valve was elevated above the pedicle valve by the septal apparatus of the latter so that a steady current of nutrient and oxygen-bearing waters could enter the lophophore cavity by way of the distal ends of the lateral lobes and leave by the median incision. Careful examination of complete, and undamaged specimens indicates, however, that the edges of the brachial valve rested everywhere in contact with a receiving notch in the pedicle valve so that the brachial valve, at rest, was nowhere elevated above the pedicle (Pl. 42, fig. 3). It is apparent, then, that in order to introduce nutrient currents into the lophophore cavity, the brachial valve had to be

elevated, even if only slightly. Examination of a large series of oldhaminids indicates that where movement of the brachial valve of the animal was hampered by asymmetry of one or both valves, sufficient mobility was always maintained to allow slight anterior gape of the valves. Study of damaged Recent brachiopods which were dredged alive in apparent good health, indicates that the animals can continue to exist even with gape of the valves reduced to a very slight amount.

While the specific ancestors of the oldhaminids are not yet known, it is nevertheless true that all candidates for the position possess a normal entire and protective brachial valve. This is borne out also by the ontogeny of *Poikilosakos* in which the pinnate valve develops from an initially simple one. If the deductions of Williams are valid, then at some point both in phylogeny and ontogeny the brachial valve no longer was needed to serve a protective function. This suggestion does not clash with the known increase in the complexity of lobation of the brachial valve with time, for the valve freed of its former protective function could develop almost without regard for reduction in strength. The idea does seem to be at variance, however, with the trend toward secondary strengthening which is manifest in several later stocks. *Coscinophora* shows one modification in the direction of increasing strength. Here the posterior plate-like portion of the brachial valve has become extremely massive and has incorporated a considerable portion of the valve. In addition dissepiments have developed between the lateral lobes uniting them at regular intervals. As has been pointed out above, the brachial valve of the oldhaminids can be interpreted meaningfully only by relating it to a ptycholophus lophophore. The dissepiments of *Coscinophora* do not bear any conceivable relationship to the lophophore and seem meaningful only if interpreted as an adaptation toward strengthening, a feature of doubtful value in an immobile internal plate. This conclusion is supported by the concomitant increase in the thickness of the pedicle valve, and may be related to a change in niche occupation such as invasion of a very rough water habitat.

The trend toward strengthening is also manifest in the last known member of the oldhaminid stock, the Upper Triassic genus, *Pterophloios*. In this form the brachial valve has become completely altered so as to present a secondarily smooth margin. It was definitely protective in function and covered the entire pedicle valve. This type of development is difficult to reconcile with the concept of an immobile, internal lophophore support.

A final, though indirect, bit of evidence may be of interest here. Contrary to the assertion made by Williams (1953, p. 280), in discussing oldhamanid shell micro-struc-

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EXPLANATION OF PLATE 41

FIG. *1,4,6,8—Adriana? guadalupensis* Stehli, n. sp. *1*, interior of pedicle valve (A.M.N.H. 27935:1) attached to a brachial valve of *Psilonotus* sp. and showing the two main trunks, ×3. *4*, profile of same specimen in assumed growth position showing the characteristic conical form of the pedicle valve, ×2. *6*, pedicle interior of same specimen showing the calcereous sheath which surrounded the large diductor muscle, ×3. *8*, pedicle interior (A.M.N.H. 27935:2) showing the septal apparatus and calcareous muscle sheath, ×3.

*3—Leptodus* sp. (C.I.T. 5949). Interior of a fragmentary brachial valve showing the ridge believed to have been the site of lophophore attachment, ×1.

*2,5—Pseudoleptodus getawayensis* Stehli, n. gen., n. sp. *2*, hinge region of pedicle interior showing the asymmetrical musculature as indicated by the calcareous sheath of the right diductor (A.M.N.H. 27934:1), ×2. *5*, profile (A.M.N.H. 27934:2) showing the assumed growth habit and the conconical form, ×2.

*7,9–13—Rigbyella girtyi* (Wanner & Sieverts). *7*, pedicle interior showing symmetrical adductor scars. (A.M.N.H. 29733:1), ×2.5; *9*, pedicle interior same specimen showing straight edged medial grooves and lobate lateral lobes, ×2. *10*, complete specimen (A.M.N.H. 27933:2) showing the brachial valve in place, ×4. *11*, pedicle valve still attached to a specimen of *Stenoscisma* (A.M.N.H. 27933:3), ×3. *12*, pedicle exterior (A.M.N.H. 27933:2), note attached bryozoan, ×3. *13*, pedicle exterior (A.M.N.H. 27933:3) in position of growth, ×3.

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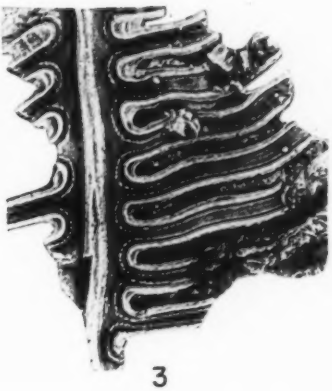

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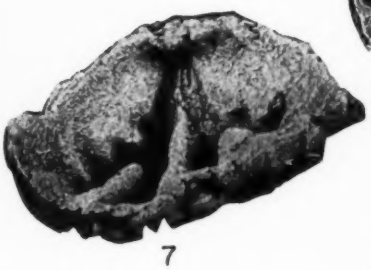

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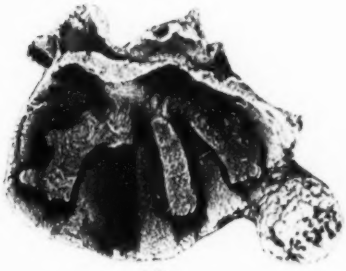

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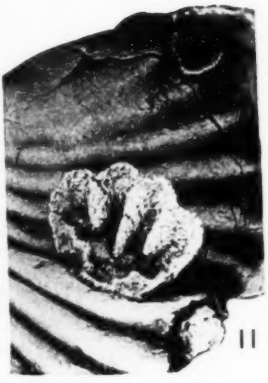

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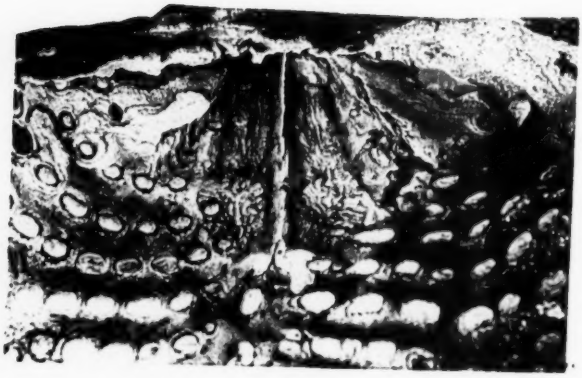

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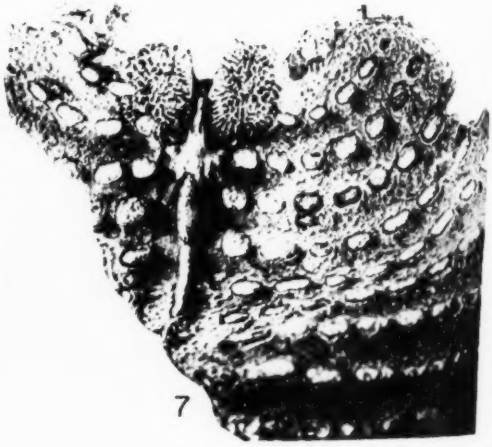

7

ture, that "the absence of the lamellar layer for so large an area is not known in any other brachiopod," the lamellar layer is completely lacking in the brachial valve of brachiopods belonging to the productaceid family Richthofenidae. The strong articulation of the richthofenid brachial valve and its undoubted complete closure of the pedicle cone, leave little doubt that it was entirely functional. It seems hardly necessary to point out that the richthofenids are a great deal closer in relationship to the oldhaminids than are the terebratuloids. A more reasonable homology may thus be drawn between the two former than the two latter groups.

In the opinion of the writer the evidence brought forward above, both direct and indirect, tends to make the hypothesis of an internal brachial valve untenable. It appears far more likely that the cells at the tip of the mantle lobe of the oldhaminids and richthofenids either did not function as a depositional tissue beyond early ontogeny, or that at some point in the maturation of the animal, the metabolism and/or physiology of these cells was so altered that they like the rest of the mantle cells produced fibrous shell.

*Remarks on soft part anatomy, growth habit and preferred habitat.*—If, as the writer believes, the brachial valve of oldhaminids was external and functioned in part for protection, then the line along which closure took place (Pl. 42, fig. 3) marks a position to which the mantle of the pedicle valve had to be withdrawn during closure. The pedicle mantle must therefore have been remarkably retractile. One is reminded of such modern gastropods as the various species of *Cyphoma* in which a thin, film-like mantle can be extended to cover the entire outer surface of the shell.

In general, the soft part anatomy of the oldhaminids of the symmetrically muscled group seem to have closely followed the basic plan for articulate brachiopods, except for the unusually large size of the adductors in the pedicle valve and the complexly ptycholophus lophophore in the brachial valve. Among the asymmetrically muscled forms, poor impression of muscle scars leaves considerable doubt as to the mechanics of valve articulation and deviation from the normal articulate brachiopod plan is extreme.

Apparently all oldhaminids with the exception of *Oldhamina* itself, were attached throughout life by the pedicle umbo, and even this genus was attached in early ontogeny. The exact mode of attachment is rather variable, and the pedicle valve may be entirely cemented or only attached apically. The larvae seem to have settled on suitable attachment sites and then initiated cemented shell growth. In many forms secretion of the initial cementation disc was followed by an abrupt turning away from the substratum. When found attached to objects which can be confidently restored to their life position, the oldhaminids are found to live in the positions shown in Plate 41, figures 4, 5, 13. Forms living attached to crinoid stems probably hung downward.

In the Guadalupe Mountains and the

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EXPLANATION OF PLATE 42

FIG. *1,3—Pseudoleptodus getawayensis* Stehli, n. gen., n. sp. *1*, hinge region (A.M.N.H. 27934:1) showing calcareous muscle sheath; note papillae which are in reality pseudopunctae, ×4.5. *3*, pedicle interior (A.M.N.H. 27934:2) showing the ridges indicating the seat of the brachial valve, ×2.

*2,7—Coscinophora* sp. *2*, hinge region showing large adductor scars at either side of the median septum and the laterally placed diductors, ×1.5. Note also the characteristic beaded ridges of the genus. (C.I.T. 5950:1) *7*, posterior of a partial pedicle valve showing the anterior ends of the adductor scars, ×2. Note also the initiation of the pallial trunks between the muscle scars. (C.I.T. 5950:2)

*4-6—Pterophloios* sp., ×4. *4*, profile of brachial valve showing the calcareous shell material filling the inter-pinnal spaces (U.S.N.M. 108873); *5*, posterior same specimen showing geniculation of valve indicating cementation of umbo of pedicle valve. *6*, interior of brachial valve showing the characteristic pinnate structure of the oldhaminids with the secondary infilling characteristic of the genus.

Sierra Diablo where water depth can be rather closely estimated by reference to the tops of reefs on the assumption that they represent sea level, the oldhaminids prove to prefer shallow water. Scattered and probably transported shells are sometimes found in deep water areas, but large concentrations of shells essentially in place are shallow water deposits. With the exception of *Oldhamina* and those forms attaching to crinoid stems, most oldhaminids and all of the larger forms required hard bottoms. This requirement seems to have been equally well satisfied by reefs, rocky bottoms or accumulations of larger invertebrate skeletal debris. The water depth of the deposits in which oldhaminids are plentifully found suggests that they preferred to live in the illuminated zone.

*Oldhaminoid classification.*—The proper classification of the oldhaminid brachiopods has long been and still remains a perplexing question. The group has most frequently been assigned a place either among the Productacea or the Strophomenoidea. The complete absence of spines, a persistent productaceid character in any known species, seems to bar the group from a place among productaceids and by elimination strongly suggests that they are strophomenoids. No other group of brachiopods morphologically and temporally acceptable as ancestral to the oldhaminids is known, and it seems probable that they can be securely placed among the Strophomenoidea.

Williams (1953) believes that the oldhaminids can be divided into two distinct groups based on symmetry or asymmetry of the brachial valve. The results of the present study also suggest that a two-fold division can be made, but on the basis of symmetry or asymmetry of the musculature. Genera having both symmetrical and asymmetrical musculature fall within the group characterized by Williams as having symmetrical valve development. It is quite apparent that evidence afforded by valve symmetry and that afforded by muscle symmetry are not in accord, and the classification of the oldhaminids can not yet be regarded as stabilized.

The writer believes that a natural classification can be achieved only by considering all available characters and that taxonomy based on a single character must be suspect. In view of the obvious confusion still existing concerning the group, it is felt that its elevation to subordinal rank by Williams and his use of two family divisions, was unwise. Elevation of a group to higher taxonomic rank does not aid in discovering its relationships and merely serves to complicate the literature. For this reason, the writer prefers to retain the more conservative but also less misleading classification of the group into a single admittedly heterogeneous family within the Strophomenoidea pending some conclusive demonstration of lower rank relationships.

## SYSTEMATICS

### RIGBYELLA Stehli, n. gen.

*Diganosis.*—Small cup-shaped oldhaminids attached by cementation of the pedicle beak. Brachial valve symmetrical and consisting of few anteriorly directed lobes. Pedicle interior sometimes with three short myophragms immediately anterior to the hinge; musculature symmetrical.

Genotype: *Paralyttonia girtyi* Wanner & Sieverts, 1935.

### RIGBYELLA GIRTYI
(Wanner & Sieverts)
Pl. 41, fig. 7,9–13

*Leptodus americanus* GIRTY, 1908, (considered *Rigbyella girtyi* to be the young of *L. americanus*), U. S. Geol. Survey, Prof. Paper 58, pl. 4, fig. 8–8b.

*Paralyttonia girtyi* WANNER & SIEVERTS, 1935, N. Jahrb. für Min., etc., Beilage Band 74, Abt. B, p. 209–210.

*Diagnosis.*—Minute, cup-like *Rigbyella* cemented to a foreign object. Pedicle exterior with faint, irregular growth lines; attached by the beak and by a small wash of adventitious shell material; valve roughly cup-shaped, wider than long. Brachial valve symmetrical, very much reduced and consisting of four, or very rarely six, anteriorly directed lobes (when six lobes are present there are four primary lobes and each of the lateral primary lobes gives rise near the front to a smaller lobe); outer lobes bearing on their lateral margins several small irregular extensions while the median edge is straight; inner lobes straight on both edges; the four main lobes united posteriorly and terminated in a narrow hinge which is

slightly expanded at its articular edge; surface ornament destroyed by silicification in the specimens examined but probably consisting of fine papillae.

Pedicle interior with four deep troughs, corresponding to the lobes of the brachial valve, which are separated by ridges; troughs uniting posteriorly and bordered by a low ridge reaching the hinge; hinge with a triangular articular surface at either side; three low myophragms are sometimes present, parallel to one another and just anterior to the hinge, between them, or in this position when they are absent are elongate, symmetrical adductor muscle scars; diductor scars not impressed. Interior of the brachial valve unknown.

*Discussion.*—Girty (1908, pl. 4, fig. 8–8b) in his pioneer studies of the West Texas Permian figured a specimen of this species but incorrectly assigned it to *Leptodus americanus* of which he believed it to be a juvenile. This error has been pointed out by Wanner & Sieverts (1935) who place the species in the genus *Paralyttonia* under the name *P. girtyi*. Examination of a number of excellent silicified specimens from the Guadalupe Mountains of West Texas has shown that the species differs from *Paralyttonia* in many important respects. The growth habit is entirely different, *Rigbyella* being cup-like and free of the substratum except at the beak, while *Paralyttonia* is cemented by the entire outside of the pedicle valve. It further differs from *Paralyttonia* in the symmetrical development of the brachial valve and in the occasional presence of the three small myophragms in the pedicle valve.

It is quite clear from the specimens at hand that the brachial valve closely apposed the pedicle valve when closed and was completely free to articulate. The presence of symmetrically developed muscle scars in the pedicle valve suggests that it did in fact open and close.

In one specimen the pedicle valve is attached to a large specimen of *Stenoscisma*. The shell of the host shows little evidence of wear, retaining much of the recurved skirt characteristic of the genus and was almost certainly not subject to much transport. If the host shell rested on the bottom, in what would seem the only likely position, with the pedicle valve down, then the attached *Rigbyella* lived with the pedicle cup so oriented that the brachial valve was in a nearly horizontal plane.

*R. girtyi* is found in deposits which accumulated at the foot of the great Capitan reef during the latest phase of its existence. It can not be definitely ascertained whether the species lived here, where the water was between 1500 to 2000 feet deep, or whether it was a reef dweller which reached the deeper water after death, but the latter seems highly probable. Collections made in the reef, including portions of the same age as the beds containing *R. girtyi* have not revealed the species. As a statistical sample, however, the small collections hammered out of the reef are less satisfying than those obtained by acid etching of many cubic feet of the forereef limestones. Even in the silicified collections *R. girtyi* is very rare.

*Range.*—During the present investigations *R. girtyi* has been found only in the Lamar limestone member of the Bell Canyon formation. Girty (1908, p. 212) cites the species from the "Capitan formation, hill southwest of Guadalupe Point (station 2906)." Girty's stations have proved very difficult to locate as his usuage of the term Capitan was not by any means the current one. His locality map indicates that station 2906 is in an area of fault blocks and his material may have come from any Leonardian or Guadalupian horizon.

Genus PSEUDOLEPTODUS Stehli, n. gen.

Genotype: *P. getawayensis*, n. sp.

*Diagnosis.*—Moderate sized, heavy shelled oldhaminoids. Pedical valve a squat cone. Brachial valve more or less symmetrically developed. Musculature asymmetrical.

*Discussion.*—This genus differs from the superficially similar group of genera closely related to *Leptodus* in the asymmetrical development of the musculature. From other asymmetrically muscled forms it differs in its heavy shell and in its symmetrical brachial valve. It might most easily be confused with *Keyserlingina* Tschernyschew which is a rather similar cup-shaped form. *Keyserlingina*, however, as shown by Tschernyschew (1902, pl. 42, fig. 15a and text-fig. 16) in *K. schellweini*, the genotype, does not possess the calcareous sheath for housing of the right diductor muscles

which characterizes asymmetrically muscled forms. The genus thus belongs to the symmetrically muscled group and is distinctly different from *Pseudoleptodus*. This conclusion is supported also by a figure given by Fredericks (1916, pl. 4, fig. 10) which shows an internal mold of *Keyserlingina* clearly showing the absence of the muscle sheath.

PSEUDOLEPTODUS GETAWAYENSIS
Stehli, n. sp.
Pl. 41, fig. 2,5; Pl. 42, fig. 1,3

*Diagnosis.*—Moderate sized oldhaminoids. Pedicle valve heavy shelled, forming a low cone, highest at the anterior margin; growth initiated as a flat plate on the object of attachment, in subsequent growth the margins become geniculated upwards to form the adult cone; valve marked only by irregular growth wrinkles. Brachial valve unknown except insofar as its shape is reflected by the pedicle valve. Pedicle interior with a short ridge-like hinge from which two ridges diverge indicating the form of the brachial valve, except posteriorly where the ridge excludes the articular areas at the hinge; lateral ridges of the "septal apparatus" usually single and massive; median ridge beginning at some distance in front of the hinge; lateral ridges inclined at about 45 degrees to the median ridge and numbering five or more on each side; interior of the cone especially the area not covered by the brachial valve, papillose; a single large diductor muscle scar is present on the right side, inside a calcareous sheath.

*Material.*—Two nearly perfect pedicle valves. A.M.N.H. 27934:2, holotype; 27934 :1, paratype.

*Discussion.*—This species may be recognized by its thick shell, symmetrical brachial valve, moderate size and asymmetrical musculature. It seems to represent a branch of the stock which apparently originated with *Poikilosakos* that has converged with the "*Leptodus*" group in its external morphology. The species is found in association with symmetrically muscled, "*Leptodus*" forms of several types, but no other asymmetrically muscled species are found in the association. *P. getawayensis* is known only from one locality and here it occurs in what are believed to be detrital accumulations from a small reef which represented an area of firm bottom on an otherwise muddy sea floor. No specimens have yet been found in position of growth; they presumably, because of their attached habit, grew on the reef or its flanks. All the known specimens came from distinctly detrital deposits where they were found disarticulated.

*Range.*—Known only from the lower part of the Getaway limestone member of the Cherry Canyon formation in the Guadalupe Mountains of West Texas. The specimens studied were collected at American Museum of Natural History locality 512 (Newell, *et al.*, 1953, p. 223).

Genus ADRIANA de Gregorio, 1930
ADRIANA? GUADALUPENSIS
Stehli, n. sp.
Pl. 41, fig. 1,4,6,8

*Diagnosis.*—Small, Guadalupian oldhaminoids. Pedicle valve thin-shelled and forming a deep cone, highest at its anterior margin; growth initiated as a flat plate on the object of attachment; margins geniculated abruptly upwards as larger size is reached to form the adult cone; ornament consisting only of irregular growth wrinkles; shell very thin. Pedicle interior with a short ridge-like hinge at either side of which is a small, striated, triangular area for the articulation of the brachial valve; two diverging ridges run forward from the hinge ridge and, excluding the articular areas, outline the brachial valve; lateral and median ridges usually conspicuously double walled; median ridge arising a short distance anterior to the hinge; lateral ridges normally present and inclined at a low angle to the median ridge or sometimes subparallel to it, or more rarely scarcely developed; a single large diductor muscle scar is present on the right side where it is housed in an elongate shell-walled trough. Brachial valve pinnate and asymmetrical but otherwise unknown.

*Material.*—A.M.N.H. 27935; holotype A.M.N.H. 27935:1.

*Discussion.*—The reference of this species to *Adriana* must be considered, I believe, highly doubtful. Because of the inadequacy of de Gregorio's (1930) figures and description, it is thought better to make a tentative assignment to *Adriana*, rather than to propose a new generic category which may be synonymous.

The musculature of this species is similar to that of *Poikilosakos* as described by Watson (1917). That author believed that the large right muscle served an adductor function. The specimens of *Adriana? guadalupensis* examined in this study exhibit an extended calcareous sheath about this muscle which reaches almost to the position of the cardinal process. This is interpreted here to mean that the muscle served a diductor function.

*Adriana? guadalupensis* is known only from the Pinery limestone member of the Bell Canyon formation where it occurs in what are believed to be turbidity current deposits (Am. Mus. Nat. Hist. loc. 635).

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JOURNAL OF PALEONTOLOLY, VOL. 30, NO. 2, P. 314–332, PL. 43, 2 TEXT-FIG., MARCH 1956

# A REVISION OF *FENESTELLA SUBANTIQUA* AND RELATED SILURIAN FENESTELLIDS

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ABSTRACT—A revised description of the genotype of *Fenestella* Lonsdale, *F. subantiqua* d'Orbigny, is based on a study of topotypes, one of which is designated neoholotype. The species *F. capillosa* Počta and *F. patula* McCoy are considered junior synonyms of *F. subantiqua*. Restudy of all other known fenestellids from the Wenlock Silurian at Dudley, Worcestershire, established the following recognizable species: *F. lineata* Shrubsole [=?*F. exilis* Počta]; *F. rigidula* McCoy [=*F. dudleyensis* Shrubsole]; and *F. reticulata* Lonsdale [=*F. reteporata* Shrubsole, ?*Gorgonia assimilis* Lonsdale]. Two additional species originally referred to *Fenestella* appear to belong in other genera: *Semicoscinium milleri* (Lonsdale) and *Unitrypa prisca* (Goldfuss) of Lonsdale. *Polypora* (*Polyporella*) *intermedia* (Shrubsole) may be identical with *Retepora infundibulum* Lonsdale. A name is proposed for Nekhoroshev's *F.* cf. *F. assimilis* from Central Asia, *F. balkhashensis*, n. sp.

## INTRODUCTION

With the pending reinstatement of the bryozoan genus *Fenestella* Lonsdale as a *nomen conservatum*, there has been a revival of interest in the Silurian *F. subantiqua* d'Orbigny [=*F. antiqua* Lonsdale, not Goldfuss] from the Wenlock at Dudley, England. In correspondence, Dr. R. S. Bassler has emphasized the importance of preserving this species as genotype of *Fenestella*. However, Ulrich's (1890, p. 395) recommendation of *F. plebeia* (McCoy) as an "accepted type" has been followed by most students. Therefore, Condra & Elias (1941a, p. 565; 1941b, p. 339; and 1944, p. 19) requested the International Commission on Zoological Nomenclature to approve the "accepted type," but now withdraw the request. In Bassler's opinion, an important consideration in favor of *F. subantiqua*, as genotype, is the existence of well preserved topotypes to serve for precise redefinition. Availability of this material removes the chief obstacle cited by Condra & Elias. Acceptance of *F. subantiqua* instead of *F. plebeia* as genotype has little effect on the relationships of the taxon. Both species have rhythmically spaced dissepiments and thus differ from *Fenestrellina* d'Orbigny, in which the dissepiments are irregularly spaced. Bassler (1953, p. 120, 122) now regards both *Fenestella* and *Fenestrellina* as distinct and valid genera, and this concept should receive universal approval.

A trip to Europe in 1951 provided me with an opportunity to investigate the present status of the problem of *F. subantiqua* in England. Through agreement with Dr. R. S. Bassler and Dr. Helen Duncan I had taken with me to England the best specimens of the species at the National Museum identified by Dr. Bassler, as well as a set of preparations of the obverse and thin sections made by Dr. Duncan. A comparative study of Silurian species of *Fenestella* was conducted during this stay in England, and subsequently in America. It will suffice to state here, that among the materials studied in the British Museum (Natural History), the British Geological Survey and Museum, the Hunterian Museum at Glasgow University, and the Kelvingrove Museum at Glasgow, I have been able to find only one well preserved specimen of *F. subantiqua* from Dudley in which the obverse is exposed and which is sufficiently large for the purpose of redescription of the species. This specimen was donated in 1882 to the Hunterian Museum by G. W. Shrubsole; though identified by him as *Fenestella lineata* Shrubsole, it differs specifically from the latter species.

It is important to take into account the fact that more than one species of *Fenestella* occurs in the Wenlock shale, and that some of these species resemble *Fenestella subantiqua*. The analyses of *Fenestella* by d'Orbigny (1852), McCoy (1954), Shrubsole (1880), and Nekhoroshev (1929*a*,*b*) make it clear that Lonsdale, author of the genus *Fenestella*, held a much broader view

of the species *F. antiqua* Goldfuss than his contemporaries d'Orbigny and McCoy, and that now generally held. Thus, when d'Orbigny renamed Lonsdale's form *F. subantiqua*, this name was applied only to the material from the Wenlock at Dudley. As now understood, the name is applicable only to the particular specimen originally illustrated by Lonsdale in 1839. However, while it is agreed by the critics that at least two different species were included in Lonsdale's "*F. antiqua*" there has been no unanimity about the total number of species of *Fenestella* which should be recognized in the Wenlock at Dudley.

In 1929 (p. 115–117) Nekhoroshev criticized Shrubsole's (1880) rejection of all species of *Fenestella* originally described by Lonsdale because of inadequate descriptions and obscure illustrations. The author proposed that the new species introduced by Shrubsole in place of Lonsdale's names should all be reduced to junior synonyms. However, Shrubsole's *Fenestella lineata* is not conspecific with McCoy's *F. rigidula* as Nekhoroshev thought (1929a, p. 117), and *Fenestella reteporata* Shrubsole is referable to *F. reticulata* Lonsdale rather than to *Gorgonia assimilis* Lonsdale, as Nekhoroshev concluded (1929a, p. 117). Nekhoroshev is possibly right in referring *G. assimilis* to *Fenestella*, for only the reverse of this species was illustrated by Lonsdale.

Unfortunately, no one has made a thorough revision and redescription of species of *Fenestella* from the Wenlock. McCoy, Shrubsole and Nekhoroshev have each described some species and discussed the others. Also, no photographs of these Wenlockian species have ever been published. The *Fenestella* material from Dudley, though well preserved structurally, is nearly all fragmentary, and mostly with the reverse exposed. These facts make the task of critical comparison of related species more difficult than if zoaria were available in larger fragments with the obverse exposed.

An attempt is made, here, to review the status of all species of *Fenestella* from Dudley, with particular emphasis on *F. subantiqua* and the species nearest to it, such as *F. rigidula* and *F. lineata* from the Wenlock. The material from the U. S. National Museum and from the Hunterian Museum is described in detail. In the descriptive text, the quantitative data characteristic of the species are summarized in the form of *meshwork formulae*, a method worked out for fenestrate Cryptostomata by Nikiforova & Nekhoroshev, and followed by Condra & Elias (1944). These formulae employ four fundamental numbers: number of branches and fenestrules per 10 mm., and zooecia and carinal nodes per 5 mm. The four numbers are separated from each other by inclined lines. Between the second and third are a pair of lines to separate the left numbers, counted per 10 mm., from the right, counted per 5 mm. Each of the four numbers may incorporate range of variability, if such is established. Thus, the following meshwork formula indicates the measured characters for *Fenestella subantiqua* d'Orbigny.

16–19 / 9.5–10.5 // 25–26 / abt. 25–26.

*Fenestella* is quantitatively the largest genus among all bryozoans, fossil and living, and more than four hundred species are known. These species make a fairly compact group, differing from each other only in size, details of inner structure, and outer sculpture. As long as *Fenestella plebeia* McCoy was used as "accepted type" of *Fenestella*, there was no danger of over-expansion of generic contents. When application of the Rules resulted in substitution of the generic name *Fenestrellina* d'Orbigny, the concept of the genus also changed. The type of d'Orbigny's genus has irregularly spaced dissepiments and irregularly shaped fenestrules, whereas in *Fenestella* Lonsdale these elements are regularly spaced and shaped.

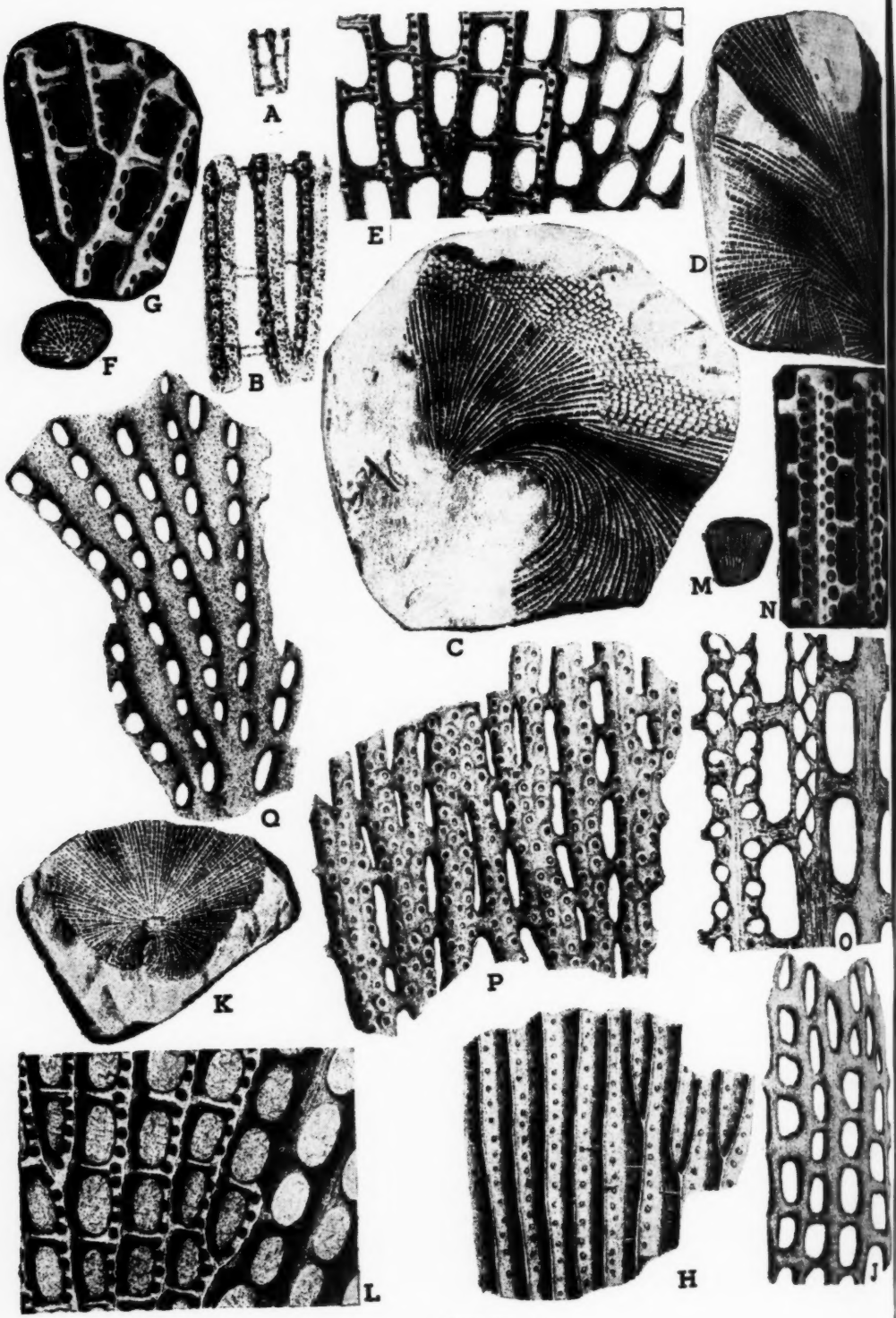
ACKNOWLEDGMENTS

I am indebted to Dr. Ray S. Bassler and Dr. Helen Duncan for their cooperation in this research and the loan of the material from the U. S. National Museum. Assistance has been rendered by Dr. Ethel D. Currie of the University of Glasgow and Mr. Terence Miller of Cambridge University. Professor T. Neville George of the University of Glasgow read the manuscript and made editorial suggestions.

## SYSTEMATIC DESCRIPTIONS

### Genus FENESTELLA Lonsdale, 1839

Among the original four species assigned by Lonsdale to *Fenestella*, only two, "*F. an-*




TEXT-FIG. 1

*tiqua,*" renamed by d'Orbigny *F. subantiqua,* and *F. reticulata* are now retained in the genus. *F. milleri* was transferred to *Semicascinium* (Nekhoroshev, 1929a, p. 116; 1929b, p. 583–584), and *F. prisca* to *Unitrypa* (Nekhoroshev, 1929a, p. 115–116; 1929b, p. 583); both latter genera were introduced subsequent to Lonsdale's work and constitute a systematic breaking up of the comprehensive genus *Fenestella.*

On the other hand, additional species of typical *Fenestella* from the Silurian of Dudley were described by McCoy (1854) and Shrubsole (1880), and some of these approach *F. subantiqua* closely. These are *F. patula* McCoy, which is here considered a probable initial part of a zoarium of *F. subantiqua;* and *F. lineata* Shrubsole, which differs from *F. subantiqua* by having a substantially larger number of fenestrules per given space, and by a smaller number of zooecia per each fenestrule. Nekhoroshev's (1929a, p. 117) suggestion that *F. lineata* is identical with *F. rigidula* McCoy is here rejected because of the great difference in the spacing of their branches and dissepiments. Altogether only four species from Dudley seem to be reasonably well established, two of which, *F. subantiqua* and *F. lineata,* though in many respects similar, differ sufficiently in spacing of branches and fenestrules for specific differentiation from each other. They are described and discussed, and new data on them are given.

### FENESTELLA SUBANTIQUA d'Orbigny

Pl. 43, fig. 1–9; Text-fig. 1-A,B

*Fenestella antiqua* LONSDALE, 1839, *in* Murchison, Silurian System, part II, p. 678, pl. 15, fig. 16,16a.

*Fenestella subantiqua* D'ORBIGNY, 1852, Prodrome de paléontologie stratigraphique, p. 180.

*Fenestella subantiqua* McCOY, 1854, Systematic description of the British Paleozoic fossils . . . , p. 50–51.

*Fenestella patula* McCOY, 1854, ibid., p. 50, pl. 1–c, fig. 20 (also McCoy, 1850, Ann. Mag. Nat. Hist., 2nd Ser., vol. 6, p. 288).

*Fenestella subantiqua* MURCHISON, 1854, Siluria, p. 180, fig. 1.

*?Fenestella capillosa* POČTA, 1894, In Barrande's Système Silurien du Centre de la Bohême, p. 61, pl. 12, figs. 1–3a.

*Fenestella* from the Wenlock at Dudley, [part] NEKHOROSHEV, 1929, Bull. Com. Geol., vol. 48, p. 115–118 (Silurian Bryozoa).

*Fenestella subantiqua* CONDRA & ELIAS, 1944, Geol. Soc. Am. Spec. Paper 53, p. 18.

*Depositories.*—Location of the holotype illustrated by Lonsdale (1839, pl. 15, fig. 16, 16a) is unknown. The selected neotype is at the University of Glasgow, Scotland, Hunterian Museum collection No. D-229. Illustrated topotypes (Pl. 43, fig. 5–9), U. S. National Museum No. 113175a and 113175b.

*Procedures.*—In the brief statement by Lonsdale about his "*Fenestella (?) antiqua,*" there is nothing about spacing of the branches, dissepiments, or zooecia, data which now serve to differentiate the various species of *Fenestella.* Only his sketch can be used, with some caution, as a guide in understanding what this species is, and how to distinguish it from other species of the genus in the material from Dudley.

Some Dudley material was selected that seemed to be nearest to the small fragmentary specimen originally illustrated by Lonsdale. First with Dr. Duncan at the U. S. National Museum, and at a later date with Mr. Terence Miller at Cambridge University, it was agreed that the number of zooecia in fenestrules as shown by Lons-

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EXPLANATION OF TEXT-FIG. 1

*A,B, Fenestella subantiqua* d'Orbigny from the Wenlock ls., Dudley. Holotype enlarged two times from the illustrations by Lonsdale, 1839, pl. 15, fig. 16,16a.

*C-E, Fenestella subantiqua?* from the Silurian of Bohemia. After Počta, 1894, pl. 12, fig. 1,2,2a, respectively.

*F,G, Fenestella patula* McCoy from the Wenlock ls., Dudley. Holotype, after McCoy, 1854, pl. 1c, fig. 20, ×1; and fig. 21, ×12.

*H,J, Fenestella lineata* Shrubsole from the Wenlock ls., Dudley. Holotype, after Shrubsole, 1880, pl. 11, fig. 2,2a; *H,* is a poor illustration, most of the dissepiments are probably obscured by the matrix; *J,* is the reverse of a fragment from the same zoarium.

*K,L, Fenestella lineata* (?) from the Silurian of Bohemia. After Počta, 1894, pl. 13, fig. 2,2a.

*M,N, Fenestella rigidula* McCoy from the Wenlock ls., Dudley. After McCoy, 1854, pl. 1–c, fig. 19, ×1; 19a, ×30.

*O, Fenestella triserialis* Ulrich from the Keokuk (Mississippian) of Kentucky, after Ulrich, ×20.

*P,Q, Polypora* (*Polyporella*) *intermedia* (Shrubsole) from the Wenlock ls., Dudley. Holotype, after Shrubsole.

dale should be considered as the most critical character in recognition of the species now known as *Fenestella subantiqua*. Thus the material at the U. S. National Museum from which Duncan made preparations and thin sections, was agreed to resemble *F. subantiqua* satisfactorily enough to serve as its topotypes. The material from the collection of the Geological Survey and Museum under study by Miller of Cambridge University does not resemble *F. subantiqua* sufficiently to be identified with it. Apparently Miller is not able to find more satisfactory material to serve as topotypes for *F. subantiqua* in the collections from Dudley stored at Cambridge University.

*Recognizable critical characters in Lonsdale's sketch.*—In the sketches published in 1839, and reproduced here enlarged twice (Text-fig. 1-A,B), the zooecial apertures can be observed and their number per fenestrules counted. It varies from about 5½ to 7½ in the three rectangular fenestrules sketched. This variation seems to reflect, at least roughly, the actual uneven spacing of the dissepiments (which determine the length of fenestrules and number of zooecia in them), as the topotypes of *F. subantiqua* here illustrated show a similar uneven spacing of dissepiments at and near bifurcation.

Because only two rectangular fenestrules in a row are shown, the count of fenestrules per 10 mm. cannot be taken with much confidence, but an extrapolation of the spacing of the dissepiments from what he sketches amounts to about 7 fenestrules per 10 mm. In an attempt to find a closely similar condition in the topotypes of *F. subantiqua* here described, I have found that in the distal part of specimen 113175b from the U. S. National Museum (Pl. 43, fig. 6) the successive fenestrules are longest, and two of them cover a maximum distance of 2½ millimeters, which, if extrapolated, would amount to about 8 fenestrules per 10 mm., or slightly more than as shown on the holotype. The count of zooecia per fenestrule on the topotype also indicates only 6½ per fenestrule as a maximum, while 7½ is the maximum number in Lonsdale's sketch.

In view of this discrepancy one may question whether the selected topotypes truly belong to the species illustrated by Lonsdale. If not, then no specimens from Dudley examined in various collections by Bassler, Duncan, Miller, and myself are referable to *F. subantiqua*, and this species must be extremely rare at Dudley. An alternative would be to admit that the selected topotypes are sufficiently close to Lonsdale's sketched fragment to fall within slight inaccuracies of his small-scale sketch made from a fragment and then lithographed. Professor T. Neville George writes me: "Surely, as extrapolation has been made, the discrepancy is of no account—note the difference in size of the two fenestrules (left hand side) of Lonsdale's figure." Thus it seems that the species *F. subantiqua* may be now accepted in its revised concept based on these topotypes, pending the remote possibility that Lonsdale's illustrated type may yet be found.

*McCoy's description.*—Neither Shrubsole (1880) nor Nekhoroshev (1929), who attempted to revise Lonsdale's (1839) and McCoy's (1850, 1854) species of *Fenestella* from Dudley, attempts to redescribe *F. antiqua* from that locality, but McCoy (1954) measured and redescribed it on material from another Silurian locality in Britain.

McCoy's work was of comparatively high quality. His data on this species seem to furnish important corroborative evidence for its differentiation from other Silurian species of *Fenestella*. McCoy characterizes it as follows (1854, p. 50):

"Sp. Ch.—Corallum formed by very slender, straight interstices [branches], seven or eight in two lines [16–18 per 10 mm.], seldom bifurcating; dissepiments rather thick, very regularly placed at about half a line apart; fenestrules rectangular, oblong, about three times longer than wide, rather more than double the width of the interstices; pores small with thickened prominent edges their own diameter apart, six or seven to the length of a fenestrule."

In the present understanding of fenestellid zoaria, McCoy's statement about "seldom bifurcating" branches means merely that the fragment or fragments which he observed represent the distal part of a zoarium. In this portion, as a rule, branches bifurcate only rarely, and they run generally parallel to subparallel to each other. His remark that the dissepiments are "placed at about half a line apart" is of course an ap-

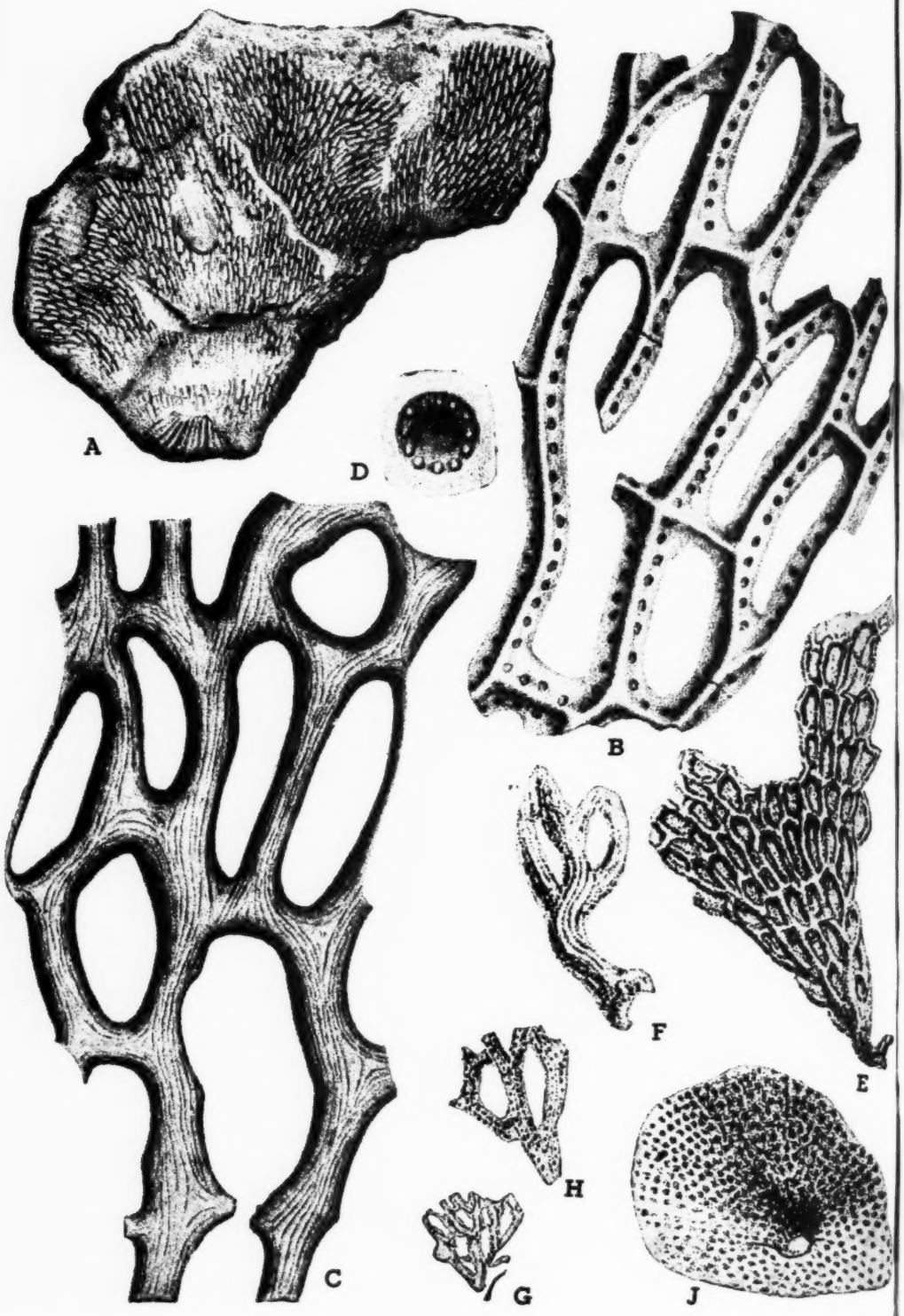
proximation of much less accuracy than in a count per given space, such as McCoy provides in the description of other species of *Fenestella*. An extrapolation based on his statement, the number of dissepiments and also of fenestrules would amount to 9–9½ per 10 mm., which is not far from 10 per 10 mm., the commonest number of fenestrules in *F. subantiqua* as here recognized. We may also suppose that "six or seven" zooecia per fenestrule observed by McCoy were probably nearer to 6 than to 7, as 6, in a few cases 6½, is the common number of apertures per fenestrule in the distal part of a zoarium of *F. subantiqua*, as here observed on the available fragments. Characteristic for this (distal) part of zoaria is also more nearly regular spacing of the dissepiments (except at bifurcations), which means subequal length of fenestrules, just as McCoy observed it on his material.

It seems clear that the concept of *F. subantiqua* by both Lonsdale and McCoy is based on distal parts of its zoarium, where branches seldom bifurcate. The hesitancy of Shrubsole and Nekhoroshev in identifying *F. subantiqua* could be explained by an apparent lack of distal parts of its zoarium in the material at their disposal.

The changes in meshwork of fenestrate zoaria, particularly that of fan-shaped ones, are to be more fully analyzed by Elias & Condra in a study of *Fenestella* and related Bryozoa from the Permian of West Texas. It will be sufficient to state here briefly that the rate of bifurcation in the branches of such zoaria, gradually diminishes from the initial part outward. In the initial part the points of bifurcations are about as frequent as connections by dissepiments, but in the most distal parts almost no bifurcations occur. Moreover, in these parts a branch may suddenly terminate and the two neighboring branches on either side of it converge at once toward each other directly above the terminus of the lost branch, until the distance between them becomes about the same as between the other local branches.

The spacing of dissepiments is more complicated, but there is this nearly universal rule for all fenestrate zoaria: the spacing of the dissepiments is less regular at and about the points of bifurcation than elsewhere. In terms of fenestrules it means that at and around the points of bifurcations they are generally most variable in length, number of apertures, width, and general outline. When about to bifurcate, a branch at first expands, and then diverges into two thinner branches within a short distance. Branches become more crowded directly above each point of bifurcation; and when more than one branch bifurcates at the same or nearly the same distance from the initial point of a zoarium, the effect of crowding of the branches becomes more conspicuous. A tendency toward such simultaneous branching seems a specific character in *Fenestella*.

*Specimen D 229 from the Hunterian Museum (Pl. 43, fig. 1–4).*—This is a fragment from a medial part of a fan-shaped zoarium, about 18 mm. long and 8–9 mm. wide, the obverse being exposed. Branches straight, or gently and uniformly outwardly curving in the left two-thirds of the specimen. The whole obverse is gently convex longitudinally, and less so transversely. Dissepiments tend to be lined up horizontally, and are more or less uniformly spaced; and yet exact measurements indicate the following slight variation in the number of fenestrules, when based on measurement of 3 or 4 successive fenestrules, and extrapolated for standard count per 10 mm.: 10½ in the basal part; 10 in lateral and upper parts; 9½ in the center of the fragment. The length of fenestrules becomes slightly more irregular at and around the points of bifurcation, where frequently the neighboring fenestrules change the number of the apertures abruptly from exactly 4 to exactly 5 per fenestrule, symmetrically spaced between the carinate dissepiments. Farther away from the points of bifurcation more fenestrules have a fractional number of apertures, and the apertures which are close to the dissepiments frequently crowd the base of the dissepimental carina. Some fenestrules in which the number of apertures is stabilized at five, with an aperture at the base of each dissepiment, occasionally occur away from bifurcations. The few longer fenestrules with six apertures each are developed only in the central part of the fragment, where there are 9½ fenestrules per 10 mm.; and they are located far from the points of bifurcation. On the other hand some wedge-shaped fenestrules directly above bifurca-




TEXT-FIG. 2

tion have as many as six apertures on each side, but such non-rectangular fenestrules are generally not considered when establishing the characteristic number of apertures (or zooecia) per fenestrule in a species.

Branches are as wide as, or slightly wider than fenestrules, dome-shaped on the obverse, with lateral slopes averaging about 45° to their bilateral plane of symmetry, with only a slight swelling of the rounded crest of the dome to furnish a distinct outer carina. This carina is distinctly though finely striated, and very small, irregularly spaced nodes can be occasionally observed upon its crest, their number roughly corresponding to the number of apertures in a single row.

Apertures are circular but some of those between dissepiments tend to be longitudinally elongated. No distinct internal notching of peristomes (Young & Young, 1874, "*Actinostoma*") has been observed.

*Thin sections.*—Tangential thin sections (Pl. 43, fig. 3) show the internal carina as a straight, sharply outlined, but narrow central wall with parallel extinction (crossed nicols). Thinner lateral walls, which separate the chambers in each of the two rows, are slightly inclined forward at an acute angle to the inner carina. These walls are straight below, structurally independent from the carina, and less transparent than it; do not extinguish in polarized light; are faintly laminated; and their obtuse posterior angle with the lateral wall becomes rounded when near the obverse. Normally the outline of a zooecial chamber is a parallelogram with its longitudinal sides the longer, but near some dissepiments the chambers become perceptibly shorter, nearly rhombic, and expand laterally into a dissepiment with an outward bulge. The apertures arise exactly at this bulge, thus swinging away from their regular row, while the shortened zooecial chamber remains within it.

The strongly outlined inner carina merges downward with a thin "basal plate," which gently curves around the bottom of the zooecial chambers, and upon its reverse arise numerous low longitudinal ribs. These interconnected structures make a continuous skeletal unit-crystal, indicated by polarized light. The longitudinal ribs produce what are called "striae," usually five or six, on the reverse of the branches. The unit-crystal system is outwardly encrusted by more or less laminated sclerenchyma, which also builds the dissepiments. It is penetrated transverse to the lamination by crowded and somewhat staggered spicules or filaments. These features are arranged in longitudinal rows as they start from near the crests of the basal ribs, and also frequently arise from lower levels of sclerenchyma when near axes of dissepiments; but they never start from the inside of zooecial chambers.

*Meshwork formula:* 16–19 / 9.5–10.5 // 25–26 / abt. 25–26; 4 to 6 apertures per fenestrule.

*Specimens 113175 from the U. S. National Museum.*—Two fragmentary specimens from Dudley at the U. S. National Museum, which are recognized by Bassler as *F. subantiqua*, were originally on a single slab. They have now been cut out, and are on two smaller slabs labelled 113175*a* (Pl. 43, fig. 5) and 113175*b* (Pl. 43, fig. 6). Because in both of these fragments the reverse is exposed, Miss Duncan separated and prepared from them four portions, and mounted them separately, after exposing their obverse (Pl. 43, figs. 7,8). She also prepared two thin sections, one from each of the specimens, *a* (Pl. 43, fig. 9) and *b*. The larger specimen *a* is 28 mm. long and was

EXPLANATION OF TEXT-FIG. 2

*A–D, Fenestella reticulata* Lonsdale from the Wenlock ls., Dudley. After Shrubsole, 1880, and *D*, probably about ×150.

*E,F, Fenestella reticulata* Lonsdale? from the Wenlock ls., Dudley. Enlarged two times from Lonsdale, 1839, pl. 15, fig. 27,27a.

*G–H, Fenestella reticulata* Lonsdale. Holotype from the Wenlock ls., Dudley. Enlarged two times from Lonsdale.

*J, Retepora infundibulum* Lonsdale from the Wenlock ls., Dudley. Enlarged two times from Lonsdale.

about 18 mm. wide prior to removal of the prepared portions in its left upper area. In addition, the upper right area is slightly ground down so as to expose some zooecial chambers.

The specimen 113175*a* (Pl. 43, fig. 5) apparently represents about the middle of a fan-shaped zoarium with a moderate number of bifurcations. The bifurcations are symmetrical and have a tendency to occur at nearly the same level, so that, for instance, eight branches out of sixteen bifurcate within a level of two fenestrules slightly below the middle of the specimen. This results in distinct crowding of branches, so that while there are about 20 branches per 10 mm. below, their number increases to 25 above the zone of this level of intense bifurcation. All branches are straight, and diverge from each other fairly rapidly and more or less uniformly. There is a slight longitudinal folding of the zoarium, so that the longitudinally medial part and the left edge are depressed, while the intermediate longitudinal strip between them (comprising some 10–12 branches) is gently elevated.

The dissepiments tend to line up horizontally. The spacing of fenestrules is mostly 10 per 10 mm., but is reduced to 9½ and to 9 in the distal part of the specimen, above the level of the crowded bifurcations of the branches. In the polished surface and in the thin sections (all belonging to the distal portion of the specimen) 5 to 6 zooecia occur per fenestrule, and bifurcation of branches rarely takes place.

The smaller specimen *b* is 10 mm. long and 12 mm. wide. Its branches occasionally bifurcate in the lower half and at the right side of its upper half, where they curve strongly to the right; but in the center of its upper half the branches of the right and left sides converge at an acute angle, and a few of them terminate abruptly when reaching the medial line of the bilaterally symmetrical convergence—a situation suggesting the position of the fragmentary specimen in a more or less distal portion of a right side of a zoarium. Its fenestrules are spaced 10 per 10 mm., slightly fewer (9½) in the area of convergence, and slightly more (10½ or 11) in the area of strong curvature of the branches to the right. The slight erosion of this specimen, whose reverse is exposed, makes visible the dimly outlined zooecial chambers beneath the semitransparent "basal plate," and it is possible to count their number per fenestrule. The number varies from 4 to 5 in the right side, and even reaches 6 in the fenestrules just below a point of bifurcation, where the three nearest bifurcations take place at about the same level. Elsewhere the number of zooecia varies from 4 to 5½ per fenestrule. The thin section 113175*a* (Pl. 43, fig. 9) shows a strong median septum between the rows of zooecia with the thinner lateral partitions inclined slightly forward, so that the outline of the chambers is in the form of a parallelogram. Usually the chambers are about 1½ to 2 times as long as wide, with a distinct tendency to become shorter when nearing some of the dissepiments. If located exactly at the base of a dissepiment, such chambers are not only short, but also expand transversely into the area of the dissepiment, and terminate there in a vestibulum, which is indicated by a rounded outline.

Thin section 113175*b* cut from the upper right side of specimen *b* shows six zooecia per fenestrule, all zooecia being abnormally short; they are as wide as long. Their spacing here is 27–28 per 5 mm., while elsewhere it is only 25–26 per 5 mm.

The laminated sclerenchyma, which encrusts the "basal plate," is penetrated transversely by a multitude of spicules or filaments 1 to 7$\mu$ in diameter, rising in several sub-regular rows in the narrow grooves between the inner ribs of the reverse of the "basal plate." At one point of this tangential section, where zooecia are traversed at the highest level of the apertures, one circular aperture shows distinct inner dentitions (eight symmetrical dents) like those described and illustrated by Young & Young (1874) for "*Actinostoma*." It seems that this structure is located so high in a vestibulum that it is usually eroded.

Comprehensive diagnosis of *Fenestella subantiqua*.—From the evidence of the topotype material from Dudley in accord with data in the literature, the following diagnosis can be formulated. The unusual amount of detail is believed important in view of the growing tendency toward splitting of the very comprehensive genus *Fenestella*.

Zoarium in form of fan whose distal part is gently longitudinally folded. Branches generally as wide as fenestrules, and the depressed dissepiments generally almost as wide as branches; fenestrules are from 1½ to 2 times as high as wide. Dissepiments between several neighboring branches frequently tend to run at about same level, but in a few cases are arranged alternately. Dissepiments are somewhat carinate on obverse and their carinae tend to fuse with the carinae of the branches, as they rise toward the branches from the middle of dissepiments, below the level of the branches. On reverse, branches and dissepiments are at about the same level.

Obverse of branches dome-shaped, with apertures only slightly raised above the flat lateral slopes, whose junction produces a carina. Carina only slightly expanded over the crest of the dome, with extremely low, somewhat irregularly spaced nodes, about as many as there are apertures. Apertures with low peristomes, circular to elliptically elongated longitudinally, not always regularly spaced, as they occasionally become more crowded when at and near some dissepiments; their number per fenestrule varies from 4 to 6, with some tendency to stabilize in exact numbers of 4, 5, or 6, the groups separated by the bases of carinate dissepiments. On the other hand, in many instances apertures assume a position of being very near to or at the center of dissepimental bases, and occasionally even tend to invade such dissepiments. However, tangential thin sections show no actual invasion of dissepiment by any zooecial chamber beyond those which follow each other side-by-side in the two rows of each branch; and the observed tendency of invasion is the result of deflection of vestibulum from a position in a row to a more lateral location in the direction of dissepiment. In such a case the zooecial chamber becomes shorter, but by becoming wider preserves its normal inner space. In tangential sections most chambers have a shape of parallelogram, with longer sides parallel to the axis of a branch, and shorter sides forwardly inclined at a moderately sharp angle to the straight vertical axial plate. However, several chambers in a row may become shorter as they become also wider, thus assuming a sub-rhombic to rhombic outline; in such chambers the outer side of the romb becomes rounded at higher level because of the concordant lateral shifting of the vestibulum.

Internally, a zoarium consists of a highly ramified skeletal core, which extinguishes simultaneously in polarized light. It is composed of straight, vertical plates, each located along an axis of a branch, and basal plates perpendicular to them, each curving around the bases of the two rows of zooecial chambers. Five or six low parallel ribs rise from the lower surface of a curved plate, and when exposed on the reverse of a branch they make it appear "striate." However, they are usually covered by finely laminated sclerenchyma, which on the reverse is usually about as thick as the height of the zooecial chambers underneath. The sclerenchyma makes the reverse of branches rounded and smooth. Sclerenchyma envelopes the whole zoarium, and is usually penetrated by densely spaced transverse spicules or filaments. They arise from near the crests of the ribs or between them, and run more or less perpendicular to lamination of the sclerenchyma. Dissepiments have an inner core which is somewhat irregular, but also extinguishes in polarized light together with the core of the branches; it is also surrounded by sclerenchyma in which may be embedded shorter transverse filaments. The unit-crystal plate-like core is usually up to 3 to 6$\mu$ thick.

The transverse spicules or filaments vary from 1 to 7$\mu$ in diameter, the larger and smaller ones being usually irregularly mixed and spaced irregularly, from a distance equal to their own diameter, to about 4 or 5 times as much apart. When viewed longitudinally they are nearly straight, with only minute offsets. When near them the filaments tend to line up parallel to near ribs, but diverge from this arrangement when farther away. They occur elsewhere in sclerenchyma, and invariably tend to be perpendicular to the zoarial surface and to the lamination of the sclerenchyma.

*F. patula* as a probable basal part of *F. subantiqua* (Text-fig. 1-F,G).—Critical comparison of *F. subantiqua* with McCoy's *F. patula* from Dudley tends to indicate that the latter is an initial part of an *F. subanti-*

*qua* zoarium. Both its branches and dissepiments are carinate, the dissepiments are lined up horizontally, and it has 10 to 11 fenestrules per 10 mm., a very characteristic number of fenestrules for *F. antiqua*. Most fenestrules in the enlarged figure (Text-fig. 1-G) of *F. patula* (McCoy, 1854, pl. 1-C, fig. 20a) have 4 to 5½ apertures, and where only three are shown (right side of the central branch, second fenestrule from below), there is a vacant space between these and the next apertures, both above and below. Such a space would accommodate exactly one more aperture, with enough interval left on either side of it so as to make a set of apertures spaced just like the rest of them in the branches of this specimen. In the great majority of the thin sections illustrated for various species of Paleozoic *Fenestella* the zooecial chambers are usually equal to subequal, and always follow each other in a row uninterruptedly, in close contact; each has an outlet in the obverse called an aperture. However, in *F. subantiqua* the zooecia occasionally become shorter near the bases of dissepiments. If there were no apertures in the vacant spaces mentioned, as McCoy's drawing shows, then the chambers underlying the apertures on either side of them would have to be elongated 1½ to 2 times as compared with those underlying all other apertures shown in this specimen; very unlikely in view of the general behavior of zooecial chambers. Hence, it seems justifiable to consider that "*F. patula*" actually has 4 to 5½ apertures or zooecia per fenestrule, some of them perhaps obscure and missed in McCoy's drawing.

The specimen is clearly the initial part of a fan-shaped (not conical) zoarium. The intensity of bifurcation, and the resulting smaller number of apertures per fenestrule, are typical for initial parts. When this factor is taken into account, it is easy to fit the holotype of *F. patula* into a zoarium of *F. subantiqua*.

### FENESTELLA LINEATA Shrubsole

Pl. 43, fig. 5 (left side), 10; Text-fig. 1-H,J

*Fenestella lineata* SHRUBSOLE, 1880, Quart. Jour. Geol. Soc. London, vol. 36, p. 249–250; pl. 11, fig. 2,2a.

*?Fenestella exilis* POČTA, 1894, *in* Barrande Système Silurien du Centre de la Bohême, p. 62–63; pl. 13, fig. 1–7.

***Shrubsole's material*** (Text-fig. 1-H,J).—The original description of this species is as follows, Shrubsole, 1880, p. 249: "*Sp. char.* Polyzoary, base strong, cylindrical or conical, attachment solid; growth, rapidly opening outwards, forming wide funnel-shaped expansion, folded or plaited on their outer margins. Five or six inches in diameter. Interstices [branches] on the poriferous face, keeled, rounded when perfect, often angular from erosion; reverse, finely striated longitudinally. Ten interstices [branches] in the space of two lines transversely. Keel, fine, straight, with slight prominences; as seen when freshly or partially weathered out, it appears as a series of very regular and parallel lines, suggestive of its specific name. Dissepiments on pore-side thin, recessed, often expanding at the junction with the interstices [branches]; seven dissepiments in the space of two lines longitudinally. Pores placed on the outer surface of the polyzoarium, small, round, prominent, own diameter apart, one or two between dissepiments, and one in each angle formed by junction of dissepiments with interstice [branch]; latter feature not always persistent, in which case there are three or four pores between dissepiments. Fenestrules on the reverse face oblong, becoming oval towards the base of the polyzoarium."

The most characteristic features of this form, as based on the just quoted description and illustrations by Shrubsole, may be formulated as follows:

Zoarium funnel-shaped, rapidly expanding, with apertures facing outwards; branches 20 to 24 per 10 mm., zooecia 25 to 30 per 5 mm.; carina thin, with very small nodes; dissepiments thin, carinate (Shrubsole's fig. 2), depressed on obverse, flush with branches on reverse (Shrubsole's fig. 2a); apertures circular, their own diameter apart, apparently about 3½ per fenestrule, tending to be stabilized in threes or fours between the bases of the dissepiments, but occasionally occupying the latter, in which case there may be up to nearly five apertures per fenestrule; reverse of branches striate.

***Specimen 113175a from the U. S. National Museum*** (*Pl. 43, fig. 5,10*).—This is a small fragment on a slab from Dudley next to a much larger fragment of *F. subantiqua*. This fragment of *F. lineata* is 8 mm. long and 4

mm. wide, with obverse exposed. Three bifurcations are developed, indicating a more or less proximal position of this fragment in a zoarium, but certainly not at its very base. Branches are carinate, the carinae covered with delicate striae clearly seen on their slightly etched surface; there are also very gentle elevations upon the carina which are about as numerous as the apertures in an adjacent row. Dissepiments average about ⅔ the width of the branches, depressed on the obverse, distinctly carinate; apertures circular, their own diameter apart, with thin, slightly raised peristomes, which are notched on the inside so as to produce an outline of an eight-rayed star; apertures tend to stabilize in fours between the bases of the carinate dissepiments, but occasionally depart from this arrangment, so that one aperture occasionally occupies the base of a dissepiment, in which case the number of apertures usually becomes 4½ per fenestrule. Branches from 18 to 22 per 10 mm., fenestrules from 12 to 13 per 10 mm., and apertures 26 to 27 per 5 mm. Zooecial chamber has the outline of a parallelogram, with the long sides along a branch, and the short sides distally inclined to the inward prolongation of the straight carina. The measured number of fenestrules, 12 to 13 per 10 mm., is smaller than described by Shrubsole (16 per 10 mm.), or as can be measured on his Pl. 11, fig. 2a (15 per 10 mm.). However, this difference may be in part the result of different positions of the measured portions in a zoarium. Thus, in Shrubsole's illustrated detail, on which he apparently measured the spacing of the dissepiments (dissepiments are scarcely visible on this detail of the obverse), there are only a few bifurcations and these are at nearly the same level in the three neighboring branches. In the fragment described here, there are three bifurcations which are rather scattered, though in the neighboring branches the bifurcations are only one fenestrule apart longitudinally.

*Revised characteristics.*—The number of fenestrules per 10 mm. is 15 on Shrubsole's Pl. 11, fig. 2a; and the approximate number of apertures per 10 mm. is 52½, nearly the same as in the described topotype. Summarized formula, based on this and on the new example, is 18–24/12–15//26–27/25–27 (of very small elevations). The number of apertures varies from 3 to 4½ (possibly 5) per fenestrule.

Comparison with *F. subantiqua.*—The species, thus characterized, differs from *F. subantiqua* in the smaller number of apertures per fenestrule, and a larger number of fenestrules: in the latter species, as described above, there are 10 to 10½ fenestrules per 10 mm., with the number of apertures varying from 4 to 6½ (possibly to 7) per fenestrule. The number of branches is also smaller in *F. subantiqua*, where there are 16 to 19 per 10 mm. The fragmentary specimens of *F. lineata* and *F. subantiqua* in the collections at Hunterian Museum and the two specimens from the Geological Survey and Museum lent to Terence Miller of Cambridge seem to belong to *F. lineata.*

Further differences between the two species seem to lie also in their zoarial growth: Shrubsole describes that of *F. lineata* as wide funnel-shaped expansion, while the zoarium of *F. subantiqua* is here deduced to be fan-shaped.

In all other morphologic and anatomic respects the two species are similar, which apparently indicates their close affinity. *F. lineata* approaches *F. antiqua* of the Devonian and *F. plebeia* of the Lower Carboniferous in the number of zooecia per fenestrule and in general zoarial aspect. The similarities between the four mentioned species of different ages apparently caused difficulties in their differentiation in the past. Even now it may perhaps be questioned whether *F. lineata* should not be considered a mere variation of *F. subantigua*, with shorter fenestrules. It would seem justifiable to say that in view of the undoubted affinity of the two species, their evolutionary differentiation probably started only slightly earlier than Wenlockian time. From a stratigraphic point of view, *F. subantigua* in an emended or restricted sense, is perhaps a better index fossil of the Wenlock than *F. lineata;* the latter form continued to live into later time, and probably evolved into *F. antiqua* of the Devonian.

*Bohemian species.*—The validity of the differentiation of *F. subantiqua* from *F. lineata* finds support in Počta's similar differentiation of two species of *Fenestella*

in the Silurian of Bohemia. Počta described in 1894 a large number of new species of *Fenestella*, with no attempt to compare them with others previously established in the Silurian and other Paleozoic systems in other regions of the world; hence it is not surprising to find that a few of his species are identical with those from elsewhere. What seems most significant, however, is that two of his species: *F. capillosa* and *F. exilis* are differentiated from each other on about the same grounds as *F. subantiqua* is differentiated from *F. lineata*. When measuring and counting various zoarial characters on Počta's drawings the following formulae for the meshwork of his two species are obtained:

*F. capillosa*:14–15/9.5–11//22–28/none?
*F. exilis*: 15–20/12–13//22–25/none?

The correspondence of the number of fenestrules and zooecia per given space in these species, and in *F. subantiqua* and *F. lineata* respectively, is as close as one could possibily expect, considering obvious inaccuracies in the sketched illustrations. In the enlarged details, which may be expected to be somewhat more accurate, the number of apertures is shown to be from 4½ to 7 per fenestrule in *F. capillosa*, and from 3 to 4½ per fenestrule in *F. exilis*, corresponding even more closely to the two British species. Furthermore, the detailed sketch of *F. capillosa* (Text-fig. 1-E) shows some apertures much displaced from their normal position by the carina of the branches; so much so that the dissepiments could be easily understood to carry these zooecia—a diagnostic character tending to place the species in *Septopora* instead of *Fenestella*. However, these dissepiments are shown strongly carinate, just as they are in *F. subantiqua*, which makes them quite unlike any known species of *Septopora*. Indeed, the apertures in *F. subantiqua* and *F. lineata* also encroach along the basal parts of the dissepiments. In addition, thin sections demonstrate the zooecial chambers remain wholly within the row of the chambers which fill the axial part of the branches and not a single zooecium actually occupies the basal part of a dissepiment. It seems permissible to entertain some doubt whether Počta meant to show these apertures so much out of line, or exaggerated the way that they tend to encroach upon the dissepiments.

Discounting this and other slight inaccuracies in Počta's drawings, the morphology of his species seems to be much the same as in the two corresponding British Silurian species. Thus, in the enlargement of *F. capillosa* (Počta, 1894, pl. 12, fig. 2a) the branches are shown carinate, and so are the dissepiments, but the latter are shown somewhat depressed; dissepiments are narrower than branches; apertures are circular and their own diameter apart; and reverse of branches, which are exfoliated in the right part of the illustrated details, is striate, the striations shown as impressions in the matrix. The impressions of the exfoliated dissepiments too are shown striated, but with the striae parallel to those of the branches—an obvious error of the sketch. This error is not repeated, however, on another enlarged detail (Počta, 1894, pl. 12, fig. 3a) of the same species, which illustrates the reverse, and in which the branches are longitudinally striated, and the thin dissepiments are shown with a single line along their middle.

It seems that the spacing of the branches in both species of Počta is appreciably wider than in the two species from the Wenlock, respectively. Because of this difference their identity with the species from the Wenlock is considered somewhat uncertain.

A complete zoarium of *F. capillosa* is certaintly not a funnel, but a conically curved and folded fan, with large lateral festoons (Počta's pl. 12, fig. 1,2). However, fig. 3 on the same plate shows what could be a small and wide cone.

The zoaria of *F. exilis* (Počta, 1894, pl. 13, fig. 1,3), which are smaller than in *F. capillosa*, are shown as unruptured, rapidly expanding funnels, folded on the periphery. His figure reproduced as Text-fig. 1-K, shows a similar funnel, but with a distinctly lopsided development, accompanied by a rupture in the shorter side, and curved edges on either side of the rupture. This form seems to be transitional toward development of a regular fan with lateral festoons. The numerous zoaria of two forms illustrated by Počta seem to further emphasize their close affinity to each other. The

zoarium in *F. capillosa* is normally a fan (just as in *F. subantiqua*), and *F. exilis* is normally a funnel (as in *F. lineata*).

*Fenestella antiqua* and *Fenestella plebeia*.—Much confusion exists regarding fenestellids which at various times became known as *Fenestella antiqua*. Goldfuss was in the habit of giving the specific name *antiqua* to various Paleozoic fossils whenever he believed them to be only specifically different from representatives of living genera. Thus, he so named inadvertently what is now recognized as two different species of the same fenestellid genus from the Devonian of Eifel: one as *Retepora antiqua* (1826; 1862 ed. p. 27; pl. 9, fig. 10a, 10b) and the other as *Gorgonia antiqua* (1826, 1862 ed. p. 99; pl. 36, fig. 3a, 3b). When Lonsdale questionably compared one of his Siliurian fenestellids with Goldfuss's "*antiqua*" he clearly indicated that he meant the "*Gorgonia antiqua?* Goldfuss, Petref. p. 99, Taf. XXXVI, f. 3a. 1826" (Lonsdale, 1837, p. 678). However, the other species, *Retepora antiqua*, became involved in a comparative study with the fenestellids from the Silurian and the Devonian of Britain, since McCoy (1854, p. 75) made a reference to "*Fenestella antiqua* (Gold. Sp. )"and attributed it to "*Retepora antiqua* Gold. Pet. Germ. T. 36, f. 3," thus mixing in the quoted reference, the name of one form with the illustration of another. Whidborne (1895, p. 167) pointed out this error by McCoy, and correctly reasoned that McCoy actually identified his form from the Devonian limestone of Plymouth with Goldfuss's *Retepora antiqua* because he mentioned that both have "short thick dissepiments," whereas this is not the case in Goldfuss's illustrated *Gorgonia antiqua*.

In studying Goldfuss's collections at Bonn, Nekhoroshev (1929, p. 108) concluded that the type of *Retepora antiqua* is apparently lost. Toots (1951, p. 235–238) finds that only the type of *Gorgonia antiqua* is lost, but not that of *Retepora antiqua* which he redescribes and reillustrates. Toots also suggests that the latter should be considered as the true *Fenestella antiqua* (Goldfuss); whereas *Gorgonia antiqua*, also a *Fenestella*, should be considered its homonym. However, because its type is seemingly lost, he suggests postponing its renaming until the holotype or a suitable topotype is found.

In all interpretations *F. antiqua* differs from *F. subantiqua* by its much smaller number of zooecia per fenestrule. However, *Fenestella lineata* Shrubsole resembles *F. antiqua* so closely that a possible close relationship with other Devonian fenestellids should be investigated.

The same suggestion can be made in regard to *Fenestella plebeia* from the Carboniferous of Ireland and Britain, which, according to McCoy (1854, p. 76), has been misidentified by Lonsdale and Phillips with *Fenestella antiqua*. It may be of some interest to note that when sectioning several specimens of undoubted *F. plebeia* in the Hunterian collection I observed in nearly all of them a well developed lower hemiseptum, which therefore may be considered as one of its critical characters. A similar species, also with the lower hemiseptum, has been found by me in the upper Mississippian limestones of Utah and Montana.

### FENESTELLA RIGIDULA McCoy
Text-fig. 1-M,N

*Fenestella rigidula*, McCoy, 1850, Ann. Mag Nat. Hist., 2nd ser., vol. 6, p. 288; ——, 1854, Systematic description of the British Paleozoic fossils . . . , p. 50, pl. 1–C, fig. 19,19a.

*Fenestella rigidula* [part] SHRUBSOLE, 1880, Quart. Jour. Geol. Soc. London, vol. 36, p. 248–249.

*?Fenestella dudleyensis*, SHRUBSOLE, 1880, ibid., p. 248.

*Fenestella rigidula* [part] NEKHOROSHEV, 1929, Bull. Com. Géol., Leningrad, vol. 48, p. 117.

The species was well characterized and illustrated by McCoy, but seems to have been subsequently misunderstood by both Shrubsole and Nekhoroshev.

McCoy describes it thus:

"Corallum formed of very slender, ridged, straight interstices [branches], branching seldom (at distances of about every two lines), several interstices often branching at the same height, at a very acute angle, about ten interstices in the space of two lines; mesial keel very strong, with two close rows of small alternating pores; fenestrules very regular in size, and shape, quadrangular, about one third longer than wide, their width about equalling that of the interstice,

usually three large thick-edged pores to the length of a fenestrule, and one larger at the end of each dissepiment."

This description lacks an indication of the spacing of dissepiments and fenestrules. McCoy, however, indicates the magnification "thirty diameters" for his sketch 19a, and it is possible to measure on it the spacing of the fenestrules, and thus compute their number, which is about 30–33 per 10 mm. A similarly computed number of branches on the same sketch is about 27 per 10 mm., which is close enough to McCoy's statement in the text: "about ten interstices in the space of two lines," which means about 23–24 branches per 10 mm. If there are exactly four zooecia per fenestrule, as per McCoy's sketch and description, there will be about 64 of them per 5 mm.; and direct measurement of the apertures in his sketch 19a also results in 62 to 65 per 5 mm. Thus the meshwork formula for the species would be 23–27/30–33//62–65.

Shrubsole (1880, p. 248) states that he has "not been able to verify" McCoy's statement about the carina "with two close rows of small alternating pores," and suggests that these could be remnants of "prominences," such as, he states, occur in several cases of other species of *Fenestella* described by McCoy and others. He feels, however, that the drawings and description of this species by McCoy "are so circumstantial that we cannot do otherwise than to retain it, notwithstanding the doubts I have expressed as to its identity" (Shrubsole, 1880, p. 249). This seems a wise decision, for Shrubsole's comparison of *F. rigidula* with the much coarser *F. patula* McCoy shows that he did not realize how delicate the zoarium of *F. rigidula* is. This is further indicated by the fact that he erected "provisionally" a new species of *Fenestella* from Dudley under name *Fenestella dudleyensis*, claiming that it "is much smaller than any *Fenestella* I have yet met with from either Carboniferous or Silurian formations" (ibid., p. 248), as "it has one hundred and twenty five interstices measured transversely to the inch." This means 45 branches per 10 mm., which is quite near the number of branches per 10 mm. when counted just above the level of the simultaneous bifurcation of the many branches in *F. rigidula*. My contention that *F. dudleyensis* could be McCoy's *F. rigidula* is, however, provisional; Shrubsole did not describe it in detail.

Nekhoroshev suggests, apparently on the basis of Shrubsole's comments that *F. lineata* is conspecific with McCoy's *F. rigidula*. In view of the great difference in the magnitude of their meshwork, this can hardly be so. He remarks that "the only difference between Shrubsole's species and that of McCoy consists in the two rows of tubercles indicated upon the carina in McCoy's form, while in Shrubsole's form there is only one row." Nekhoroshev assumes that Shrubsole proved that McCoy's description of "mesial keel very strong, with two close rows of small alternating pores" is tantamount to a description of a carina carrying two rows of eroded nodes; but this is not the case. Then Nekhoroshev states that "because I have not seen among the numerous Silurian bryozoa in the British Museum a single specimen of *Fenestella* which would have a double row of nodes upon its keel, I suppose that all this is mere misconception, possibly based on original observation of semi-eroded specimen, when remnants of the dense tissue between the apertures may create wrong impression of a double row of nodes" (1929, p. 117, translation from Russian).

It seems, however, that McCoy's detailed description and illustration of *F. rigidula* could have not been made on an eroded specimen, as he shows and describes thick peristomes around the large apertures, and even points out that those located at the base of the dissepiments are invariably larger than the others. Furthermore, there is no need to assume that the double row of nodes are developed *upon* the carina in *F. rigidula*. All that can be seen in McCoy's sketch are small circular holes *on either side of the carina*, where they are spaced intermittently with the apertures. That this structural situation is probably correctly sketched is borne out by the fact that in 1890 Ulrich (p. 541–542; pl. 50, fig. 4a) records a similar development of small circular structures intermittent with the zooecial apertures in *Fenestella triserialis* from the Keokuk of Kentucky, reillustrated as Text-fig. 1-O. He also writes: "a very perfect

fragment, obtained since the plates were lithographed, shows a peculiar feature not noticed at that time. At the same time it explains the small spots which are shown in sections between the cells (Pl. 50, fig. 4a). In this [additional] specimen a long tubular spine extends from the interspace between the apertures obliquely outward and upward. Being very delicate, these spines would readily give way to attrition, but since I know of its existence, I can detect its base in the other specimens." It seems that Ulrich was not aware of McCoy's observation of similar circular lateral structures in *F. rigidula*, and of Shrubsole's (1880, p. 249) suggestions that they are bases of spines. In the collection of Bryozoa from the Upper Keokuk about 1 mile south of Warsaw made by Dr. G. E. Condra and myself in 1942, there are small fragments seemingly identical with *F. triserialis*. Small circular structures are developed where Ulrich shows them, except that they are not exactly in line with the apertures but slightly closer to the carina; that is, they are near the position of the similar structures in McCoy's sketch of *F. rigidula*.

Hence it seems that the peculiar development of spines *on either side of a carina*, instead of upon or near its crest, is a characteristic feature in some rare species of *Fenestella*. If so, it would seem proper to keep in our record McCoy's *F. rigidula* from Dudley as he describes and illustrates it. Its most characteristic features would be: extraordinarily delicate meshwork; comparatively large and heavily rimmed apertures, which contact each other and are stabilized at four per fenestrule; larger apertures at the base of the dissepiments; and a prominent carina on either side of which are small circular structures, probably bases of eroded *lateral* nodes.

### FENESTELLA RETICULATA Lonsdale
### Text-fig. 2-A–2-H

*Fenestella reticulata* LONSDALE, 1839, *in* Murchison's Silurian System, p. 678, pl. 15, fig. 19,19a.
*Fenestella reteporata* SHRUBSOLE, 1880, Quart. Jour. Geol. Soc., London, vol. 36, p. 249; pl. 11, fig. 1–1c.
*Gorgonia assimilis* LONSDALE, 1839, *in* Murchison Silurian System, p. 680, pl. 15, fig. 27, 27a.

Identity of two species, *F. reticulata* Lonsdale and *F. reteporata* Shrubsole, is based on the similarity of the general design and dimensions of their meshwork. Also, on the peculiar combination of the two methods in which their meshes are built; *i.e.*, by transverse dissepiments, and by direct lateral contact of the branches.

Though the fragment illustrated by Lonsdale in detail (Text-fig. 2-G) is small, it shows the characteristic design of the meshwork just described. It shows, also, a peculiar angular flexuosity of the branches. Another character common to both species is the occasional presence of apertures on either side of the carina in some carinate dissepiments. The fact that both Lonsdale and Shrubsole show these dissepimental carinae and the dissepimental apertures seems to indicate their undoubted existence. These characteristic features are apparently not repeated in any other species from Dudley or in any other known species of *Fenestella*. Because of this peculiarity, the species may be considered transitional between *Fenestella* and *Septopora;* the occasional lateral contacts of its branches place it close to *Reteporina* (=*?Semicoscinium*).

Characteristics of *F. reticulata* listed by Lonsdale are brief (1839, p. 678): "Branches irregularly anastomosed: foramina large, rather distant: reticulation of the inner surface similar to that of the external." This analysis indicates that he was cognizant of the "irregular" manner in which the branches are interconnected.

Shrubsole characterizes *F. reteporata* as follows (1880, p. 244): "Polyzoary, base conical, opening outwards, forming expansions of considerable size. Interstices [branches] obverse, strong, sinuous, keeled, rounded, often angular from erosion; reverse, striated longitudinally: four interstices in the space of two lines transversely. Keel strong, rounded. Dissepiments often less in size than interstices, recessed, not so wide as fenestrules, giving in consequence a waved line to the interstice; two dissepiments in the space of two lines longitudinally. Pores small, circular, less than their diameter apart when not worn down; from eight to thirteen pores between dissepiments. Fenestrules irregular, oblong, narrower at either end, twice as long as broad." He adds that: "Its ample size, irregular habits of growth, and large number of pores

between dissepiments are its distinguishing features, . . . "

The fact that Lonsdale referred to the apertures as "large" and "rather distant" in spacing, while Shrubsole describes them as "small" and "less than their diameter apart when not worn down" should not be construed as indicative of an actual difference between the two species in these respects. If the corresponding drawings by Lonsdale and Shrubsole are placed side-by-side (Text-fig. 2-E and 2-G), no differences can be detected in size and spacing of the apertures. There is only a difference in understanding of what is "large" and "small" in the descriptions by these two authors; the undoubted similarities seem to be more important. There is also considerable similarity in the size of various zoarial elements. In the two sketches by Lonsdale, one can measure about 8 branches per 10 mm. and 5½ fenestrules per 10 mm., while there are about 30 apertures per 5 mm.; and the number of apertures per fenestrules varies from 9 to 16. Shrubsole's measurements (recalculated in millimeters) amount to 10 branches per 10 mm., 5 fenestrules per 10 mm., and 20 to 25 apertures per 5 mm.; while the apertures number from 8 to 13 per fenestrule.

The only difference that can be noted, the number of apertures per given space, may be partly due to inaccuracy of sketching (particularly in those by Lonsdale) and partly to an apparent different position in a zoarium of the two respective fragments illustrated. That by Lonsdale (Text-fig. 1-P,1-Q) spreads rapidly and its branches bifurcate frequently, indicating a position at or near the base of a zoarium. Shrubsole's illustrations (Text-fig. 2-A to 2-C) obviously belong somewhere in a full grown part of the zoarium, where bifurcations are moderately frequent, while the sub-parallel branches spread out slowly. The greater variability in the number of apertures per fenestrule in Lonsdale's, compared with Shrubsole's, specimens harmonizes with the greater frequency of the bifurcations in the former.

*Meshwork formula.*—Measurements on Lonsdale's sketch result in the following meshwork formula: 8/5½//abt. 30; while Shrubsole's data may be summarized in the formula: 10/5//20–25. The former is characteristic of the initial part of zoarium, and the second of its full grown part. Further observations on actual material, which is not at my disposal, will undoubtedly result in more accurate formulae than these.

Nekhoroshev (1929a, p. 117) expresses an opinion that "*Fenestella reteporata* Shrubsole is identical with *Gorgonia assimilis* Lonsdale, the only difference consisting in the obscurity of Lonsdale's descriptions; but his figure 27 [of *G. assimilis*] leaves no doubt that we are dealing here with the genus *Fenestella;* and in the limestone from Dudley, where the forms described by Lonsdale and Shrubsole belong, there is only one species of *Fenestella* which has such characteristic structure and dimensions." This conclusion is based on Lonsdale and Shrubsole's illustrations and descriptions. Those of Lonsdale represent the reverse only, and in the text (p. 680) he says that he did not observe "pores," that is, apertures. His species may be therefore referred to *Fenestella* only provisionally, because of the general resemblance of the sketch by Lonsdale to *F. reteporata* Shrubsole. On the other hand the comparatively large and well illustrated specimen of Lonsdale's *G. assimilis* (Text-fig. 2-E,2-F) only 3 to 3½ fenestrules per 10 mm.; 5 fenestrules can be counted per this space in one row only, in the left-central part of the drawing.

### POLYPORA (POLYPORELLA) INTERMEDIA (Shrubsole)
Text-fig. 1-P,1-Q

*?Retepora infundibulum* LONSDALE, 1839, *in* Murchison's Silurian System, p. 679; pl. 15, fig. 24.

*Fenestella intermedia* SHRUBSOLE, 1880, Quart. Jour. Geol. Soc. London, vol. 36, p. 250–252; pl. 11, fig. 3,3a.

*?Fenestella intermedia = F. infundibulum* NEKHOROSHEV, 1929, Bull. Com. Géol., Leningrad, vol. 48, p. 117.

This Wenlockion species of *Polypora* is discussed here because it was classified with *Fenestella* by Shrubsole, and because of its role in the problem of the taxonomic significance of the position of the obverse ("poriferous side") in cone-shaped zoaria of *Fenestella*. Nekhoroshev (1929*a*, p. 117) feels certain in his identification of Shrufsole's "*Fenestella intermedia*" as Lonsdale's *Rete-*

*pora infundibulum*. He writes as follows: "Among the material from Dudley only this form has a conical zoarium with the outer surface non-poriferous [reverse], and in addition only in this form is bifurcation retarded, thanks to which cellules arranged in three rows in a branch are encountered as frequently as in two rows." This statement is based on his examination of some Dudley material at various museums; but it is also clear that Nekhoroshev has not examined the types of either Lonsdale's or Shrubsole species.

Shrubsole's diagnosis of *P. intermedia* is as follows (1880, p. 250):

"Polyzoary, extreme base solid and strong, somewhat conical in shape, ultimately forming wide open expansions. Interstices [branches] on the obverse face broad, full, and rounded, having for the length of two or three fenestrules two rows of pores. This is repeated over the expansion. The three-row series of pores immediately precede the bifurcation of the interstice. Reverse, finely striated longitudinally. Width [of branches] variable, alternately narrow and wide. Dissepiments thin, recessed, not expanding at junction with interstice; six dissepiments in the space of two lines longitudinally. Keel thin and fine between the two rows of pores; a corresponding line winding between each line of the three-row series of pores. Pores on the inside of the polyzoary small, circular, prominent, level with the keel, their diameter apart, three between dissepiments. Fenestrules on the poriferous face very narrow, wider on the reverse, nine in the space of two lines measured transversely."

In an attempt to make a meshwork formula on the measurements in this diagnosis a question arises as to what is meant by Shrubsole's count of "six dissepiments in the space of two lines." Were both dissepiments falling at the opposite ends of two lines counted in these six? If so, only five fenestrules should be counted per line. In order to verify this point, I counted the number of fenestrules on the two good drawings by Shrubsole (1880; pl. 11, fig. 3,3a). I have found, however, that both are marked in the explanation (p. 254) as magnified twelve times. Such a magnification cannot be correct for both as fig. 3 is clearly magnified twice as much as fig. 3a. In the assumption of 12 times magnification, there would be 22 fenestrules per 10 mm. in fig. 3, and 11 fenestrules per 10 mm. in fig. 3a. The latter number of fenestrules is the same as followed from Shrubsole's count of "six dissepiments in the space of two lines" if interpreted to mean 5 fenestrules per two lines, that is per 4.33 mm. It follows that Shrubsole's fig. 3a is magnified 12 times, while his fig. 3 is magnified only 6 times. Counting of branches per given space in fig. 3 on this magnification results in 20–21 per 10 mm., which is also the same as indicated in Shrubsole's diagnosis: "Nine in the space of two lines." Accepting the magnification of 6 times for fig. 3, the number of apertures per 5 mm. would be 17 to 20.

*Meshwork formula.*—These data give the following meshwork formula: 20–21/11// 17–22, with $3\frac{1}{4}$ to $3\frac{1}{2}$ apertures per fenestrule.

*"Retepora infundibulum" Lonsdale.*—Lonsdale's brief description of this species is as follows (1839, p. 679): "*R. Funnel-shaped*, branches united in a thick network, the interstices being small and variable in shape; inner surface [of branches] with two vertical rows of pores [apertures]. The arrangement of the pores is similar to that in *Fenestella*, but on the inner, and not the external surface. A very small fragment only of the interior has been examined."

Lonsdale's statement that "the arrangement of the pores is similar to that in *Fenestella*" seems to indicate that in the "very small fragment . . . of the interior . . . " examined by him only branches with two rows of apertures were represented; the branches with three rows did not happen to be present at all, though they could be present elsewhere in the zoarium. This was apparently what Nekhoroshev implied when he identified *R. infundibulum* Lonsdale with *Polypora intermedia* Shrubsole.

Approximately the same number of branches and fenestrules per given space, can be counted on Lonsdale's figure (Text-fig. 2-G) and as is established for Shrubsole's species. The possibility cannot be ruled out that Lonsdale's species is a *Fenestella*, which only approaches Shrubsole's *Polypora intermedia* and has two rows of apertures as a rule. The three rows of

apertures extend *for a short distance* below some points of bifurcation, only. Species with this type of arrangment of apertures are well known in the Carboniferous and are customarily classified with *Fenestella: F. rudis* Ulrich, *F. limitaris* Ulrich, *F. veneris* Fisher, and others. In view of this possibility, it seems prudent to accept Shrubsole's *Polypora* (*Polyporella*) *intermiedia* as a valid species, and to keep Lonsdale's *Retepora infundibulum* in suspense as a questionable species whose obverse is insufficiently known.

FENESTELLA BALKHASHENSIS Elias, n. sp.

*Fenestella* cf. *assimilis* NEKHOROSHEV, 1933, Trans. U. Geol. and Prosp. Service of USSR, Fasc. 338, p. 8–9,15; pl. 1, fig. 3, and pl. 3, fig. 4.

Nekhoroshev considered *Fenestella assimilis* Lonsdale to be synonymous with Shrubsole's *F. reteporata* (1933, p. 8), but this view is unacceptable. Also, the form from the Silurian of Balkashland, questionably identified as *F. assimilis* cannot be referred to this species. He counted 6 to 9 fenestrules per 10 mm., and roughly 15 zooecia per 5 mm.; both counts are substantially different from the corresponding spacings of the elements in *F. reteporata* and *F. assimilis*. Thus I consider his form a new species, *Fenestella balkhashensis*, and designate as its holotype the single specimen illustrated by Nekhoroshev.

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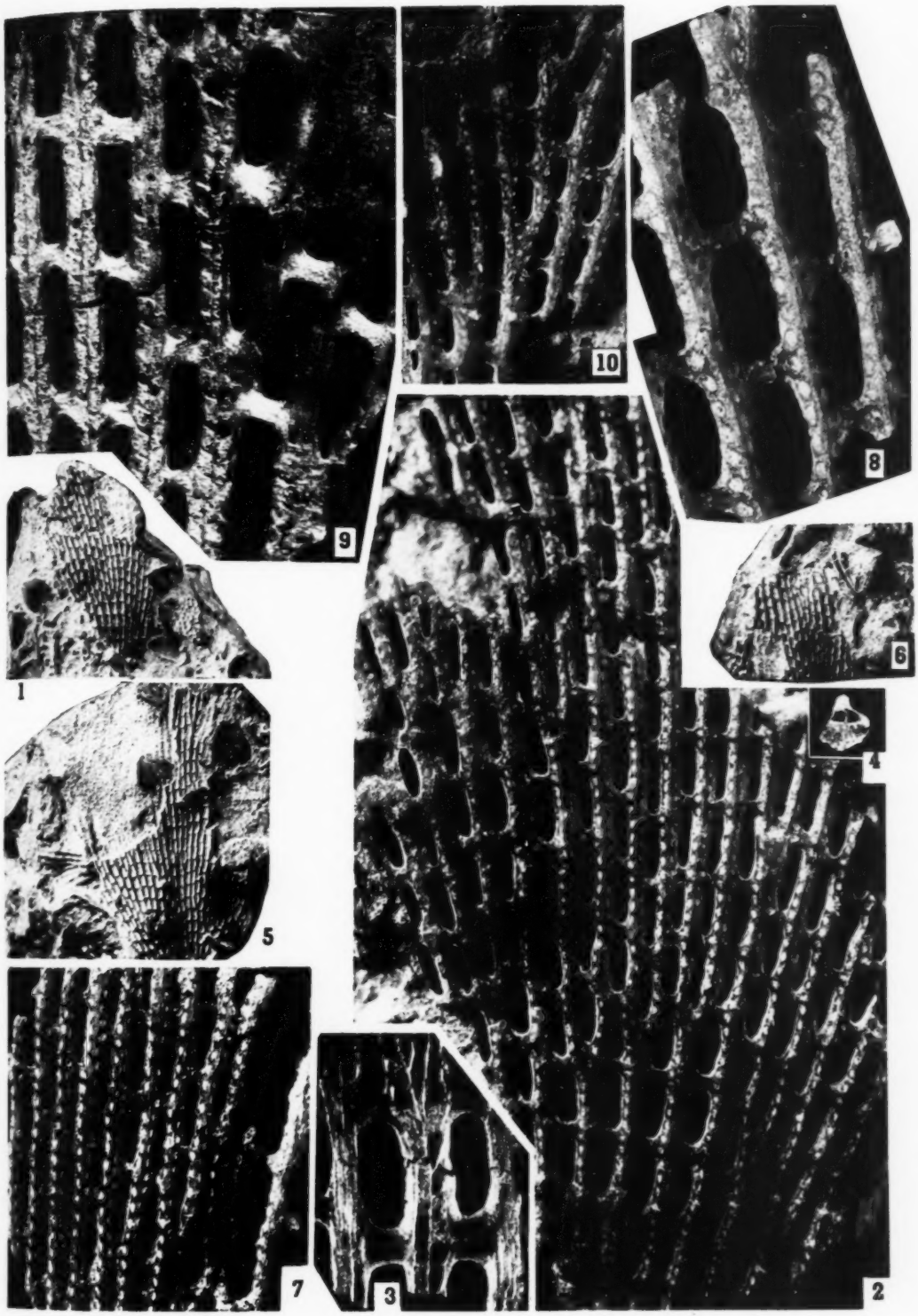
## EXPLANATION OF PLATE 43

All photographs unretouched, except that the rock matrix in the thin sections is blocked out.

FIG. *1–4—Fenestella subantiqua* d'Orbigny from the Wenlock ls., Dudley. Neoholotype, Hunterian Collection No. D 229. *1*, ×1; *2*, ×10; *3*, tangential thin section from the right upper corner of No. D 229, ×20; *4*, cross-section of a branch from the same, ×20.

*5–9—Fenestella subantiqua* d'Orbigny from the Wenlock ls., Dudley, topotypes. *5,6*, U. S. National Museum 113175a, and 113175b, ×2; *7,8*, preparation from the upper left corner to show the obverse of 113175a, ×10 and ×20; *9*, thin section from the same, ×20.

*10—Fenestella lineata* Shrubsole from the Wenlock ls., Dudley, topotype. U. S. National Museum 113175a, ×10; in *5*, this species is on the same slab with *F. subantiqua*.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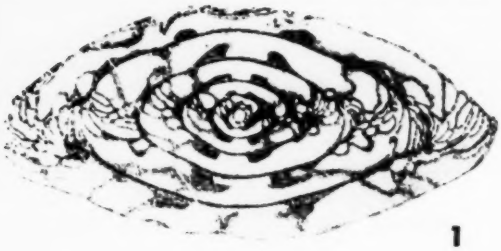

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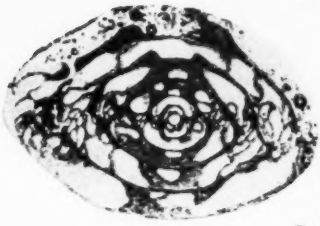

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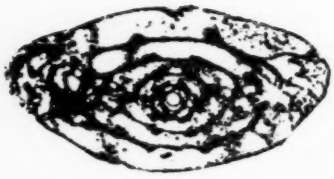

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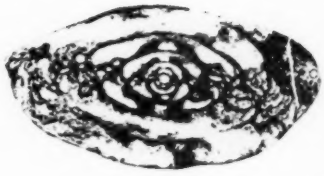

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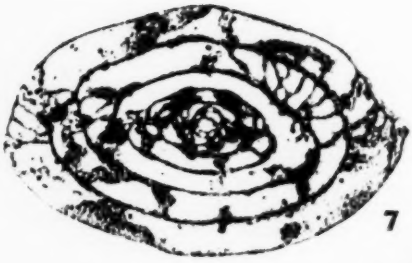

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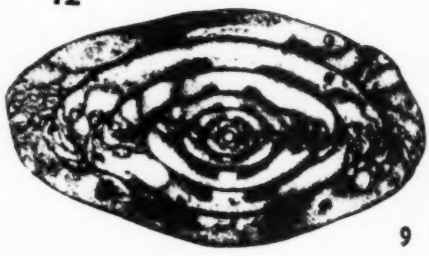

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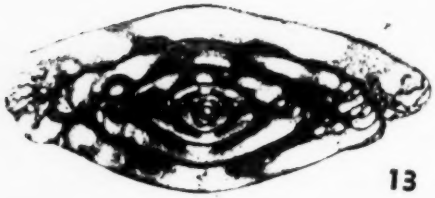

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JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 2, P. 333–337, PL. 44, 1 TEXT-FIG., MARCH 1956

# *PROFUSULINELLA* IN WESTERN UTAH

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ABSTRACT—Thick Pennsylvanian limestones occur in the Conger Mountains of the Confusion Range of western Utah stratigraphically above the dark Mississippian shales with ammonoid faunas of Meramecian age. The lower of these limestones contains a *Millerella* fauna and other fossils which suggest Morrowan age. Above the probable Morrowan rocks are limestones of Morrowan or lower Derryan age with abundant *Millerella* and *Staffella*, and above these are limestones with a fusulinid fauna of *Millerella* and *Profusulinella regia* of lower Derryan age. This is the first *Profusulinella* to be described from western Utah.

THE first American species of the genus *Profusulinella* Rauser-Cernoussova & Beljaev, 1936, was described in 1935 from Pennsylvanian shale of southern Oklahoma as *Fusulinella fittsi* Thompson. A few years later the genus was observed through a relatively thick section of rocks of lower Derryan age over a wide area in southern New Mexico and western Texas (Thompson, 1942, 1948) and in central Texas (Thompson, 1947). At all places so far observed, the genus occurs in rocks of Derryan age and immediately below primitive faunas of *Fusulinella*. Its stratigraphic range seems restricted to this part of the section, it is the most primitive of the elongate fusiform group of fusulinids, and it is the major index fossil of the lower Middle Pennsylvanian that has been designated as the Zone of *Profusulinella*.

The broad aspects of Pennsylvanian paleogeography seem to indicate that lower Pennsylvanian seas were widespread in central United States and deposited limestone and shale of Morrowan age over much of central and western Texas, Oklahoma southern Kansas, Colorado, western Wyoming, and eastern Utah, and perhaps southern New Mexico. Post-Morrowan disturbances and uplifts, followed by widespread erosion, resulted in the removal of parts of these marine deposits in many regions. However, with the beginning of Middle Pennsylvanian time the seas intermittently but gradually spread farther and farther by overlap into the central United States area. The first of these advancing seas contained very abundant faunas of the genus *Profusulinella*, and the presence of this genus is important in the interpretation of the paleogeographic history of this marine invasion. It should be pointed out that this major invasion of Middle Pennsylvanian seas culminated in the widespread Desmoinesian rocks which doubtless have the most widespread distribution of any of the Pennsylvanian.

We recently studied the Pennsylvanian rocks stratigraphically above the dark shales with a Meramecian ammonoid fauna ex-

EXPLANATION OF PLATE 44

All illustrations on this plate are unretouched photographs, and all are magnified ×20.

FIG. *1–12*—*Profusulinella regia* Thompson. *1–5*, Axial sections from Utah; *6*, axial section from Bed 14, Section 15 west of Silver City, New Mexico; *7,8*, axial sections of paratypes; *9*, axial section of the holotype; *10,11*, sagittal sections from Utah; and *12*, tangential section from Utah. *1* to *5* and *10* and *11* are of specimens 1, 3, 6, 4, 5, 7, and 6, respectively, of measurement data.

*13*—*Profusulinella apodacensis* Thompson. Axial section of the holotype from the Apodaca formation of New Mexico.

*14*—*Profusulinella spicata* Thompson. Axial section of the holotype from the Apodaca formation of New Mexico.

posed on Wedding Cake Mountain in western Utah and found a succession of fusulinids which indicates that the lower limestone carries a prolific fauna of *Millerella*, followed in ascending order by faunas of *Millerella* and *Staffella*, and that in turn by faunas of *Millerella* and abundant *Profusulinella*. Since *Profusulinella* has proved of such value for age determination, the occurrence of the genus in western Utah seems worthy of special consideration.

The nearest geographic occurrence* previously noted for *Profusulinella* is in western New Mexico where abundant faunas occur in the lower Derryan rocks exposed just west of Silver City. At this locality *Profusulinella* faunas considered to be of about the same age as the Wedding Cake fauna occur in a limestone about 87 feet above the Mississippian, and more advanced *Profusulinella* faunas occur above this position at Silver City. A similar fauna is found about 170 feet above the lowest of the *Profusulinella P. copiosa* Thompson, further east in southern New Mexico and western Texas. As is to be expected, upper *Profusulinella* faunas are considerably more widespread than the lower *Profusulinella* faunas. It seems significant that the Wedding Cake *Profusulinella* is an advanced form of the genus. However, the local paleogeography is too poorly known to determine directions of invasions and overlap, if such can be determined in the immediate area of Wedding Cake Mountain.

The general lithology of the stratigraphic section at Wedding Cake Mountain which contains the fusulinids is shown on the accompanying diagrammatic illustration (Text-fig. 1). For comparative purposes, the section exposed above the Mississippian limestone west of Silver City and some of its fusulinids are shown on the same diagram. The lower part of the limestone exposed above the Mississippian shales at Wedding Cake Mountain contains megafossils and fusulinids which suggest that they may be Morrowan in age. The next 80 to 100 feet of limestones carry an abundant fauna of *Millerella* and less abundant *Staffella*. Although *Staffella* is generally considered of lower Derryan or younger age, it is realized that these rocks may be of upper Morrowan age or lower Derryan age. The first abundant larger fusulinids in the Pennsylvanian at Wedding Cake Mountain are referable to *Profusulinella regia* Thompson originally described from the lower Derryan of the Hueco Mountains of Texas. The highest fusulinid-bearing Pennsylvanian rocks at Wedding Cake Mountain contain *Fusulinella* and are overlain unconformably by Permian Wolfcampian limestones.

* Since this paper was written, Dott (Am. Assoc. Petroleum Geol., Bull., vol. 39, p. 2211–2305, 1955) reported *Profusulinella* from several places in eastern Nevada.

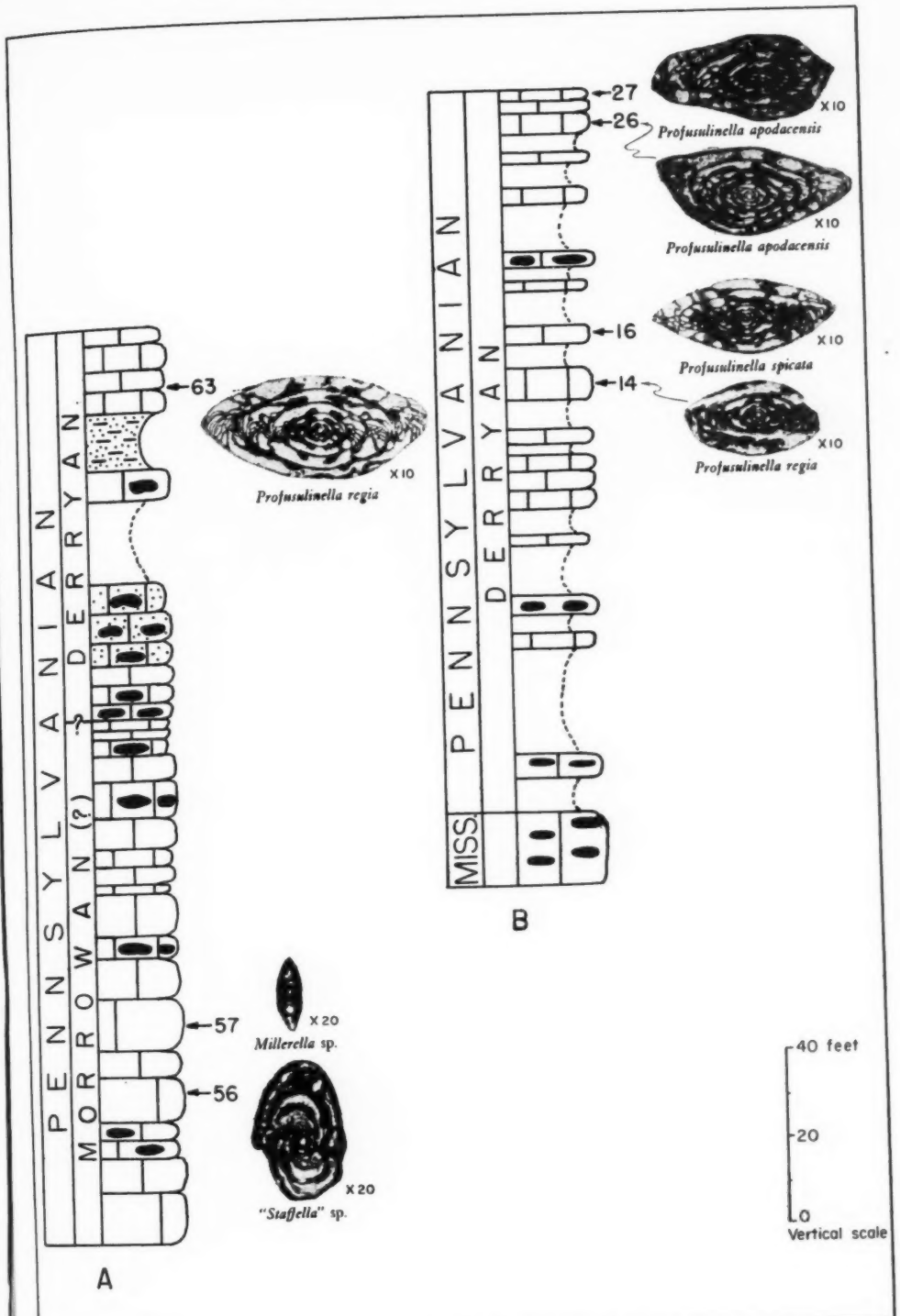
PROFUSULINELLA REGIA Thompson
Pl. 44, fig. 1–12

*Profusulinella regia* THOMPSON, 1948, Univ. Kansas Paleont. Contrib., Protozoa, Art. 1, pp. 83–85, pl. 1, fig. 1, pl. 27, fig. 7,8,13, pl. 30, fig. 8–19.

The shell of *Profusulinella regia* Thompson is large and inflated fusiform in shape and has bluntly pointed polar ends, convex lateral slopes, and a straight axis of coiling. Specimens of five to six volutions measure 2.0 to 3.4 mm. long and 1.1 to 1.5 mm. wide, giving form ratios of 1.8 to 2.5 and averaging 2.0 for five specimens. Our largest specimen is 3.4 mm. long and 1.5 mm. wide, giving a form ratio of 2.3. The first volution is about spherical in shape and the axial ends gradually become extended and the shape becomes more and more distinctly fusiform. Averages of the form ratios of the first to the sixth volution of five specimens are 1.3, 1.6, 1.7, 1.9, 2.0, and 1.9, respectively.

The proloculus is small and spherical in shape and has an outside diameter of 71 to 100 microns, averaging 88 microns for seven specimens. The chambers are lowest above the tunnel, and they increase in height rather rapidly toward the polar ends near which they become about half again as high as above the tunnel. The shell expands about uniformly throughout its growth. Averages of the height of chambers above the tunnel in the first to the sixth volution of seven specimens are 43, 60, 85, 124, 181, and 226 microns, respectively.

The spirotheca is composed of a tectum and upper and lower tectoria. The lower tectorium is considerably thinner than the




TEXT-FIG. 1—Diagrammatic illustration of Pennsylvanian rocks of western Utah (A) and western New Mexico (B), with some fusulinids.

TABLE 1.—MEASUREMENTS OF *Profusulinella regia* THOMPSON FROM WESTERN UTAH, IN MILLIMETERS

| Specimen | L. | W. | Ratio | Diam. of prol. | Height of volutions | | | | | | Form ratio of volutions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 3.4 | 1.5 | 2.3 | .092 | .041 | .070 | .104 | .147 | .203 | .234 | 1.5 | 1.8 | 1.8 | 2.5 | 2.0 | 2.3 |
| 2 | 2.8 | 1.1 | 2.5 | .100 | .062 | .069 | .100 | .132 | .157 | — | 1.5 | 1.8 | 1.9 | 2.1 | 2.5 | — |
| 3 | 2.2 | 1.5 | 1.5 | .096 | .044 | .063 | .099 | .129 | .149 | — | 1.2 | 1.3 | 1.4 | 1.4 | 1.6 | 1.5 |
| 4 | 2.4 | 1.3 | 1.8 | .082 | .037 | .051 | .083 | .107 | .195 | .219 | 1.0 | 1.4 | 1.6 | 1.8 | 1.9 | 1.8 |
| 5 | 2.0 | 1.1 | 1.8 | .097 | .041 | .074 | .096 | .144 | .233 | — | 1.5 | 1.7 | 1.8 | 1.9 | 1.8 | — |
| 6 | — | 1.2 | — | .075 | .038 | .053 | .066 | .127 | .200 | — | — | — | — | — | — | — |
| 7 | — | 1.0 | — | .071 | .037 | .043 | .048 | .084 | .127 | — | — | — | — | — | — | — |

| Specimen | Thickness of spirotheca | | | | | | Septal count | | | | | | Tunnel angle (degrees) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 33 | 39 | 50 | 58 |
| 2 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 41 | 48 | 83 | — |
| 3 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 27 | 33 | 33 | — |
| 4 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 26 | 28 | 31 | 36 |
| 5 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 25 | 36 | 50 | — |
| 6 | — | — | — | — | — | — | 8 | 12 | 14 | 15 | 18 | — | — | — | — | — | — | — |
| 7 | — | — | — | — | — | — | 8 | 10 | 13 | 16 | 16 | — | — | — | — | — | — | — |

upper, but both are variable in thickness across the width of the chambers.

The septa are moderately widely spaced and their spacing increases gradually throughout the shell. They are almost perfectly plane in the center of the shell throughout their heights, but broad fluting is developed in the lateral quarters of the shell that fail to bring adjacent septa in contact except in the extreme polar regions. Averages of the septal counts of the first to the fifth volution of two specimens are 8, 11, 14, 16, and 17, respectively.

The tunnel is broad and has a path that is only slightly irregular. It is only about a third to a fourth as high as the chambers. Averages of the tunnel angles in the third to the sixth volution of five specimens are 30, 37, 49, and 47 degrees, respectively. The chomata are small and have steep to overhanging tunnel sides and steep poleward slopes. In areas adjacent to the septa they extend almost to the top of the the chambers.

*Remarks.*—The specimens from Wedding Cake Mountain on which the above description is based resemble the holotype and paratype specimens of *Profusulinella regia* from Texas in regard to most measurable features and in regard to most observable features. Of the few differences which can be pointed out, the form ratios of the Utah specimens become slightly greater toward maturity, their chomata are slightly larger, and their proloculi are smaller. These differences are considered regional variations and not of specific or subspecific importance.

*Profusulinella regia* resembles rather closely *P. apodacensis* Thompson from the Apodaca formation of New Mexico. However, it is slightly larger for corresponding volutions, has a more loosely coiled shell, and has much smaller and more narrow chomata. The chomata structure and shell expansion alone would serve to distinguish these species.

We are illustrating on the accompanying diagram (Text-fig. 1) various fusulinids from the Wedding Cake Mountain section and from the section of the Derryan measured west of Silver City, New Mexico. The fusulinids from the Silver City section are referable to *Profusulinella regia*, *P. spicata* Thompson, and *P. apodacensis*, the latter two of which were described originally from the Apodaca formation of central New Mexico. *P. regia* differs from *P. spicata* by the more inflated and more rapidly expanding shall, much smaller and more narrow chomata, and the more uniformly ellipsoidal shell of the former.

*Occurrence.*—*Profusulinella regia* is abundant in Bed 63 of the section measured on Wedding Cake Mountain (Text-fig. 1) at the south end of Conger Mountain located in the Confusion Range, sec. 15, T. 18. S., R. 16 W., Millard County, Utah. The primary types of the species are from the upper

part of the Green Canyon group exposed in Powwow Canyon in the Hueco Mountains of Texas. The species is common about 87 feet above the base of the Derryan in the southeast corner of the NE ¼, sec. 4, T. 18 S., R. 14 W., 1.1 miles west of the Court House in Silver City, Grant County, New Mexico.

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JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 2, P. 338–344, PL. 45, 1 TEXT-FIG., MARCH 1956

# OBSERVATIONS ON THE MORPHOLOGY OF *ASTRODAPSIS*

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ABSTRACT—Although the genus *Astrodapsis* is now generally assigned to the family Scutellidae, some of the early primitive forms were at one time questionably assigned to the family Clypeastridae. The internal morphology of specimens of *Astrodapsis* and the spines demonstrate that this genus belongs to the Scutellidae.

The author studied the internal morphology particularly the position of the auricles and the character of the internal walls and pillars of some Miocene species. The structure of the auricles did not seem to be significant but their position was quite diagnostic. The presence or absence of internal walls and pillars and their structure were found to be of determinative value. Of the external features, the spines showed definite family affinities to the Scutellidae.

## INTRODUCTION

WHILE making a systematic study of the Echini, I found the morphologic features of some specimens of *Astrodapsis* to establish definitely the scutellid affinities of this genus. Many years ago, John C. Merriam questionably assigned *Astrodapsis brewerianus* Remond, a primitive ancestral form, to *Clypeaster*, and some more recent paleontologists have verbally questioned its assignment to the family Scutellidae. The large suite of Miocene *Astrodapsis* from the Cuyama Valley region of the California Coast Ranges, collected largely by Major Joseph E. Eaton, permitted the sectioning and dissection of numerous specimens for study of the internal morphology. On the actinal (ventral) surface of a few of these specimens the spines are still attached.

This paper is based largely on a comparative study of these specimens and others belonging to closely related genera. Specimens of the following species were studied: *Astrodapsis cuyamanus* Kew, *A. woodringi* Eaton and Grant, and *Echinarachnius merriami* (Anderson) of Miocene age, *A. peltoides* Anderson and Martin of Pliocene age, and *Dendraster excentricus* Eschscholtz, *Clypeaster speciosus* Verrill, *Encope californica* Verrill, and *Mellita longifissa* Michelin of the Recent fauna.

## ACKNOWLEDGMENTS

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## SYSTEMATICS

### Family CLYPEASTRIDAE A. Agassiz

Test moderately high or flattened with a distinct petaloid arrangment of the pore pairs. Anal opening marginal or inframarginal. Apical system central with five genital plates fused into one, and with five genopores. On the dorsal surface, the ambulacral plates often reduce the interambulacrum to a narrow band near the apical system. Adradial sutures diverge sharply near the end of the petals, the distance depending on the maturity of the specimen. Ambulacral furrows straight, never becoming ramified; oral surface generally depressed around the peristome. Spines long and thin with a small condyle and base. Tubercles small, perforate, and crenulate, with deeply incised scrobicles. Internally, pillars and walls highly developed; five pairs of thin, parallel walls extending from the edge of the peristome to approximately one-half the distance to the margin. These walls very low and approximate in position the adradial sutures. Marginal ends of the walls terminate in a complexity of pillars, which often form an arc-like series across the ambulacra. Between the ends of the parallel walls, and the wall of the test, pillars

are absent to provide space for the alimentary canal. Auricles low, separate, arising from the aforementioned walls, each being placed on a half-ambulacrum. In some instances, the auricle plates appear to cover a portion of the neighboring interambulacrum (Pl. 45, fig. 4). Aristotle's lantern simple and modified from that of Regular Echini, with the jaws articulating on the auricles (Pl. 45, fig. 5).

### Family SCUTELLIDAE L. Agassiz

Ventral surface of the test relatively flat' the dorsal surface slightly to moderately inflated, sometimes accentuated in the apical region. Outline of the test variable, ranging from nearly round to oblong, or truncated posteriorly, sometimes slightly pentagonal. Marginal notches may be present, usually ambulacral in position. (In *Rotula*, notches are also interambulacral.) Lunules ambulacral or in interambulacrum 5. (In *Rotula* they are in interambulacra 2 and 3.) Pore-pairs more or less petaloid with varying degrees of closure, but in no known species do the petals become entirely closed. Adradial sutures diverging from the petals at varying distances from the margin. Actinal ambulacral furrows simple in less specialized genera, but in the specialized forms furrows become increasingly more bifurcated. Spines of the ventral surface relatively short compared with the width of the base, the latter flaring noticeably from the shaft. Dorsal spines with the same base and shaft as the ventral spines, but end of the spine greatly modified into a spade-like form. Tubercles vary in size with the spines, relatively small, often crenulate, indistinctly perforate. Internally pillars and walls highly developed, especially in the specialized forms. Primitive forms with two walls extending from the peristome to the margin on each interambulacrum and, in many specimens, continuing up around the margin and for a slight distance on the internal side of the aboral surface. The walls reflect the divergence of the ambulacral plates, often showing a reverse petaloid structure from that seen on the aboral surface. Height of the walls variable, apparently with no set height within genera, however, never extending the full height of the body cavity. In the later forms, these walls ramify into a strengthening complex of pillars close to the margin. Auricles low, fused together and resting on the interambulacra, generally close to the peristome (Pl. 45, fig. 1,3). Aristotle's lantern specialized, extremely flat in some forms, articulating directly on the auricles; teeth horizontal (Pl. 45, fig. 2). Braces, or rotulae absent.

*Internal morphology.*—In this study only a few Pliocene specimens preserved on friable sandstones were available to us and none of these could be sacrificed for dissection. Consequently, the author was compelled to use some of the abundant Miocene specimens, all of which were preserved in well consolidated sandstone or siltstone. The matrix in the specimens was thus very hard, often consisting almost entirely of calcite. Selected specimens were ground on an emery wheel, beginning on the dorsal surface and working downward so that any parts of the lantern that might be preserved would remain intact. Also, this procedure permitted determination of the position of the auricles. On the ventral surface of some specimens the spines were still present in attached position. These were extracted from the surrounding matrix and studied under a microscope.

*Auricles.*—In the genus *Clypeaster*, the auricles are on the ambulacral plates. They are high, each one approximately at the adradial suture, and the two auricles composing a pair are thus separated by some distance. A varying amount of the base of the auricle extends over the primordial interambulacral plate (Pl. 45, fig. 4). This latter variance seems to be an indication of age, for in the young of the same species, the auricles do not cover as much of the interambulacrum as the older specimens. The lateral migration of the auricles appears to represent an ontogenetic trend which may indicate the past evolutionary changes in the ancestral line. The end result of the trend would be fusion of the auricles on the interambulacra (Pl. 45, fig. 3). This, of course, is the case in the family Scutellidae. It seems probable, therefore, that a split occurred in the primordial ancestral stock, perhaps in early Eocene, with the clypeasters remaining somewhat primitive in this

character, and the scutellids carrying on the evolutionary trend of complete fusion of the auricles situated on the primordial interambulacral plates.

In the family Scutellidae, the auricles are fused in an interambulacral position in all forms (Pl. 45, fig. 1,3,6). They are always low and placed at varying distances from the peristome. The angle of the pyramids of the lantern reflect the low height of the auricles, as the angle is always obtuse (Pl. 45, fig. 2,7). In the later forms the auricles, although still on the primordial plates, have moved back from the peristome further accentuating the low lantern angle. The auricles of *Echinarachnius merriami*, *Astrodapsis* and *Dendraster* all show the typical scutellid form. In the first two, the auricles are extremely low and placed directly on the edge of the peristome. Between the auricles there is a marginal ridge, which cannot be called an apophysis as it is actually an extension of the basicoronal ambulacral plates in each area. In *Echinarachnius merriami* the auricles are narrow, oblong-shaped and actually appear as mere low protuberances at the end of the interambulacra. Auricles of *Astrodapsis* are also low, but are broader than those of *E. merriami*, nearly square in shape and more sturdy in appearance. They are clearly fused along a suture through the center. The actual height of the auricles is not definitely known. However, the lantern is less procumbent in *Astrodapsis* than in *Echinarachnius merriami* and as the auricles in each genus are on the edge of the peristome, it follows that the auricles of *Astrodapsis* should be higher.

In *Dendraster* the author noted what is apparently a progressive evolutionary trend in the auricles, as they are removed from peristome a short distance on the primordial interambulacral plates. Again the auricles are connected by a low collar around the peristome, and in this case, it is clearly seen that the collar is not an apophysis but merely an extension of the peristomal margins of the ambulacral plates. The removal from the peristome, coupled with the low height of the auricles, results in (or from) an extremely obtuse angle in the pyramids. The auricles have become much more specialized than those of *Astrodapsis*, being thin, delicate protuberances arising from a slightly raised interambulacral plate. This same specialization is seen to a greater extent in *Encope* and *Mellita*.

*Internal walls.*—The internal walls of *Astrodapsis* show a considerable variation from those of *Clypeaster*. In the latter genus, as noted previously, the walls radiating from the peristome do not extend to the ambitus. A definitely delineated channelway is left clear of pillars and walls to allow room for the gut. In *Astrodapsis* the internal wall arrangement is very similar to *Echinarachius merriami* although not as pronounced. Radiating from the peristome, the walls follow the adradial sutures, showing clearly the widening of the ambulacral plates toward the ambitus. The height of the walls near the peristome differs with the individual specimen probably due to growth stages within the individual. However, in no specimen studied did the walls extend from the ventral to the dorsal surface near the peristome. In all specimens the wall rose abruptly at a point approximately mid-way between the peristome and the ambitus and were continuous from dorsal to ventral sides outward from this point. *Echinarachnius merriami* has thin and clearly defined internal walls. The walls of *Astrodapsis* are not high near the peristome and do not extend the height of the inner chamber except near the margin. They are thick, show the same sturdiness seen in the auricles, and the positions are the same as those of *Echinarachnius merriami*. In each of these two genera and also in *Dendraster*, the auricles are situated between these sets of walls, while the auricles of *Clypeaster* are on the peristomal extensions of the walls.

We note, then, that the internal morphology of *Astrodapsis* resembles closely that of *Dendraster* and *Echinarachnius merriami*. The differences between these three genera may be related to their ecology. *Dendraster* lives in sheltered coves and embayments and in deep water off beaches where it is protected from the direct pounding of ocean waves. The habitat of most *Astrodapsis* of Miocene age is believed to have been the open beach, for the sands in which we find the fossil forms are those

which are generally indicative of considerable turbulence. The exceptions to this generality are those forms found in very uppermost Miocene sediments and the silts of the lower Pliocene. The seas in which these animals were living apparently became very muddy during this period of time, and possibly the thick ambitus and highly raised petals reflect an attempt by the genus to keep its respiratory mechanism from being suffocated with sediment.

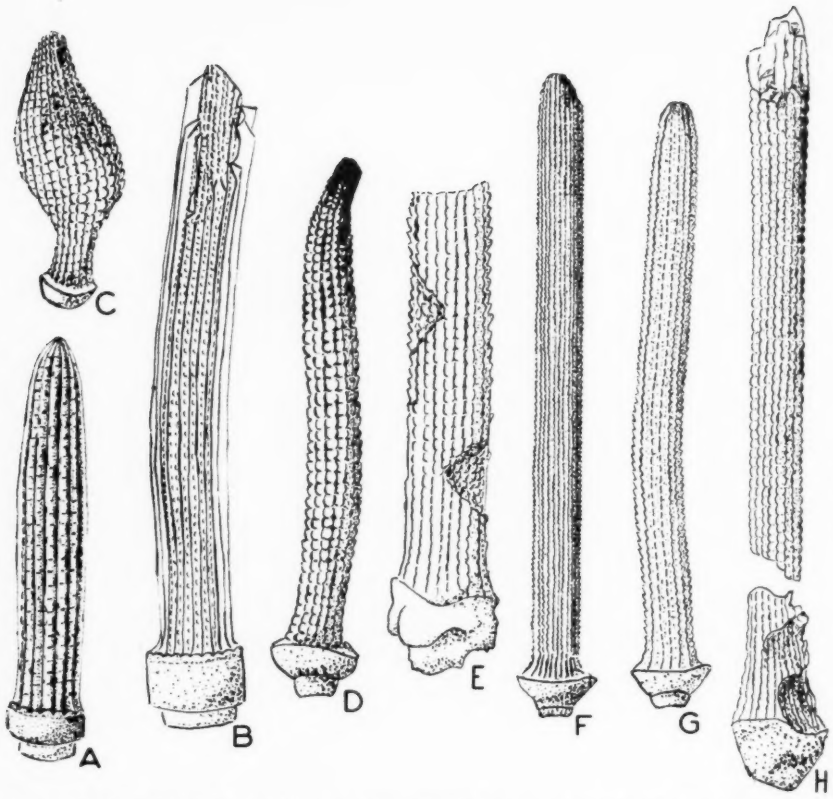
The morphology of the genus appears to corroborate other evidence of an open beach ecology for, as we have noted, the internal structure along with the test is exceedingly sturdy. *Echinarachnius merriami*, despite its thinner walls, is very strong for its size and for that reason is believed to be more of an open beach form than *Astrodapsis*. Although the matrix surrounding *E. merriami* is often quite fine, it is still coarse enough to be open-beach sand.

*Evolutionary trends.*—To say, however, that the differences of internal morphology are entirely allied with ecologic habitats would be completely misleading. The variations very likely are also an indication of evolutionary trends within the Scutellidae. Although we are not attempting to place the three genera in an evolutionary series, t is possible that each genus branched from the main scutellid stock and furthermore, *Astrodapsis* may be a descendent of a form somewhat similar to *Echinarachnius merriami*. However, without further study, we are unable to elaborate on this possibility. Nevertheless, *Astrodapsis* does appear to be an intermediate form between the primitive features of *Echinarachnius merriami* and the highly specialized structure of *Dendraster*. The auricles of *Echinarachnius merriami* are low and simple; those of *Astrodapsis* are higher and, if one could be seen in cross-section, would probably be more specialized in appearance; auricles of *Dendraster* are, as has been shown, highly specialized. The radial retreat of the auricles from the peristome probably follows closely the specialization trend of the plates. Although there is indication of movement of the plates in *Astrodapsis*, the auricles of *Dendraster* are always removed a varying distance toward the ambitus from the peristome. The distance corresponds to the age and size of the specimen, the mature forms having auricles placed approximately $\frac{1}{4}$ inch from the edge of the peristome. Probably the greatest movement of the auricle plate is realized in *Mellita* and *Encope*.

Corresponding to the apparent trend of the auricles is a change in the internal wall structure of the three genera. The internal supports in *Astrodapsis* and *Echinarachnius merriami* are simple and sturdy. Although those of *Astrodapsis* are heavier and lower than those of *Echinarachnius merriami* there is a slight indication of primitive internal pillars in the former genus. The walls of *Astrodapsis* at the ambitus appear, in many specimens, to be slightly honeycombed. This internal separation of the walls is possibly a primitive pillar system. The pillars become extremely complicated in *Dendraster* and the walls, so apparent in *Astrodapsis* and *Echinarachnius merriami*, are degenerate and nearly lost, remaining as very low ridges which do not reach the marginal ends of the internal cavity. Unlike the walls in the first two genera, those in *Dendraster* do not follow the adradial suture.

*Spines.*—While dissecting several specimens of *Astrodapsis*, we were fortunate to find numerous well-preserved ventral spines. The matrix surrounding the peristome, in which they were found, was friable enough to allow extractions without harming the spines. During the first part of the work on the spines, it was believed that a generic classification might be accomplished by using the spines alone. However, we found that the only determination possible would be of family affinities. The spines of *Echinarachnius*, *Dendraster* and *Astrodapsis* are entirely too similar for generic separation.

The primary ventral spines of the Clypeastridae are long and thin. The nodes, which are in vertical rows, are oblong in lateral cross-section and are internal in respect to the outer surface of the spine. An axial cross-section of the spine shows a transparent portion that is not continuous around the entire spine, but is projected by each row of nodes. A central plug in the spine has a granular crystalline appearance and comprises approximately half the volume of the spine. The characteristic gradual




TEXT-FIG. *1*—Various kinds of echinoid spines, greatly enlarged. *A,B, Clypeaster speciosus* Verrill, Recent, Gulf of California; from dorsal and ventral surface. *C,D, Dendraster excentricus* (Eschscholtz), Recent, southern California; from dorsal and ventral surface. *E, Astrodapsis cuyamanus* Kew, Upper Miocene, Cuyama Valley, Santa Barbara County; from ventral surface. *F, Encope californica* Verrill, Recent, Gulf of California; from ventral surface. *G, Mellita longefissa* Michelin, Recent, Lower California; from ventral surface. *H, Merriamaster* sp., Upper Pliocene (*Pecten coalingensis* zone), Zapata Creek, Fresno County; from ventral surface.

flare of the base from the shaft in scutellid spines is unlike the abrupt flare in the Clypeastridae, as the base widens from the shaft at nearly right angles. The condyle is small, both in thickness and diameter (having nearly the same radius as the shaft) and its radius remains constant throughout the length. In the mature form, the base is of greater vertical thickness than the condyle, usually in a 2:1 ratio (Text-fig. 1-A,B).

Spines of the Scutellidae have a greater variation, depending on their position on the test. The ventral spines have a rather typical slender, elongate appearance while those of the dorsal surface are greatly modified into a spade-like form (Text-fig. 1-C,D). This modified spine has only been seen, by the writer, from Recent and Pleistocene scutellids, but there seems to be reason for believing that early forms had similar modifications (Mortensen, 1948).

The spines of the ventral surface are relatively short compared to the width of the base of the spine, which flares noticeably from the shaft. The base is not thick, having a sharp outer edge, and angles back to the top of the condyle abruptly. There are, of course, variations in the thickness of the base within different genera. *Astrodapsis* shows readily the thin base, but the sharp

outer edge and sweeping flare is not visibly present (Text-fig. 1-E). It is possible that during fossilization, the spine has become compressed and these features are not preserved to the best advantage (See Plate 45). Taken as a whole, the overall appearance of the bases is quite stable. The condyle of the scutellids is generally cone-shaped with the greater diameter at the top. The diameter of the condyle is usually less than the diameter of the shaft, although in *Astrodapsis* the difference is very slight. In the primitive forms, the diameter of the condyle does not vary as greatly within the individual as in the Recent species, the cone-shaped appearance being very slight. *Merriamaster* (Text-fig. 1-H) has similar features.

The shaft of the spine shows the most striking feature of scutellid spines. Although it consists of nodes similar to those seen in the Clypeastridae, the nodes are not surrounded by an extremely transparent covering. The nodes comprise the outer surface and, thus, a vertical cross-section shows a knobby appearance similar to an ear of corn. The nodes range from a definitely rounded outer surface (*Dendraster* and *Astrodapsis*) to a sharp point appearance (*Encope* and *Mellita* in Text-fig. 1-F,G). The nodes are arranged in parallel rows with their size varying with the diameter of the shaft in the individual.

The dorsal spines have the same type of condyle, base and shaft as the ventral spines, but the end of the spine, as noted above, is modified into a spade-like form. The size, both in thickness and diameter, of the base, condyle and shaft of the dorsal spines is very close to that of the ventral spines of the same individual. When in place the spine is curved towards the margin so that the wide, flat side of the spade is facing upwards, forming an apparent protective armor. The same knobby appearance is present with the nodes arranged parallel to the edge of the spine. The central plug is present, but does not have the granular appearance as in the Clypeastridae.

## SUMMARY

By studying various features of the internal morphology of fossil and Recent echinoids it has been determined that the genus *Astrodapsis* definitely belongs to the family Scutellidae. The position of the auricles and the presence or absence of internal walls and pillars and their structures were found to be of determinative value.

In *Astrodapsis*, *Echinarachnius merriami*, *Dendraster*, *Encope*, and *Mellita*, the auricles are fused in an interambulacral position. They are always low and placed at varying distances from the peristome. This is a scutellid characteristic. In the Clypeastridae, the auricles are high and are situated on the ambulacral plates with a varying amount of the auricle extending over the primordial interambulacral plate.

In *Astrodapsis* the internal walls radiate

## EXPLANATION OF PLATE 45

FIG. *1*—*Encope californica* Verrill. Hypotype, UCLA 9131. Recent, Gulf of California, ×⅔. Abactinal portion of test removed to show interior.

*2,3*—*Dendraster excentricus* (Eschscholtz). *2*, dorsal view of Aristotle's lantern of a Recent specimen, ×2. *3*, hypotype, UCLA 9129, Recent, south of Pt. San Felipe, Gulf of California, ×⅔.

*4,5*—*Clypeaster speciosus* Verrill, Recent, Gulf of California. *4*, interior of hypotype UCLA 9128, ×⅔. *5*, dorsal view of Aristotle's lantern, ×2.

*6*—*Astrodapsis peltoides* Anderson & Martin. Hypotype, UCLA 9126, Lower Pliocene, Priest Valley, Monterey County, California.

*7*—*Astrodapsis woodringi* Eaton & Grant. Dorsal view of Aristotle's lantern from which teeth have apparently been dissolved. Lower Neroly (Upper Miocene), Branch Canyon, Cuyama Valley, Santa Barbara County, California (UCLA loc. 1852), ×2.

(See next page for plate 45)

from the peristome showing clearly the widening of the ambulacral plates toward the ambitus. Even though the height of the walls differs in the individual, in none did the walls extend from the ventral to the dorsal surface near the peristome. In *Clypeaster*, the radiating walls do not extend to the ambitus, a definitely delineated channelway being left clear of pillars and walls to allow room for the gut.

The spines of *Astrodapsis* also show definite affinities to those of other members of the family Scutellidae.

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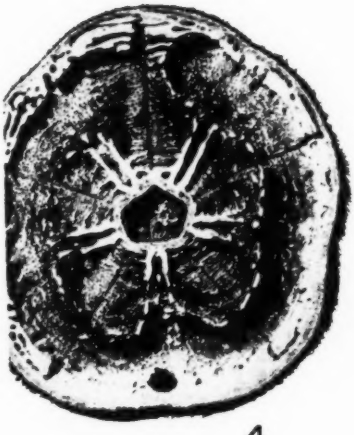

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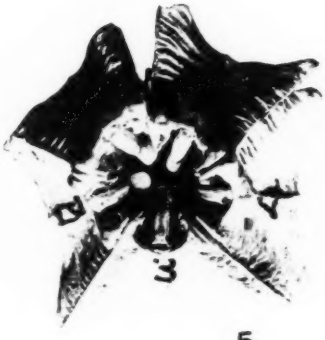

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JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 2, P. 345–351, PL. 46, 3 TEXT-FIG., MARCH 1956

# A NEW GENUS OF LOWER TRIASSIC HOLOSTEAN FISH FROM THE DOLOMITE ALPS

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ABSTRACT—The specimen on which this species is based came from the Lower Triassic of the Gardena Valley, Italy. It represents one of the very few fishes of the European Werfenian, and it shows little affinity with Permian ichthyofauna. The writer believes that it belongs in the Semionotidae.

On both sides of the fossil (part and counterpart), the head, nearly all the trunk, and the dorsal fin are preserved. In addition to the exterior details, it was possible to study in thin section the histologic structure of the very small marginal teeth and of the scales. In the position and form of some opercular bones, the new genus tends to parallel certain fishes of the Eotrias of Madagascar, which belong in the Parasemionotidae. Moreover, it reveals many characters that are to be found in stratigraphically younger genera (*Semionotus*, *Heterolepidotus*, *Paralepidotus*, and *Lepidotus*). For this reason it seems to represent a transitional form of remarkable importance from an evolutionary point of view.

## INTRODUCTION

IN 1953, on the mountains near Santa Cristina, Val Gardena, Italy, Mr. E. Moroder and the author found the fossil on which this study is based. It came from the basal beds of the Lower Triassic. The locality where the fossil was found is 2 km. north of Santa Cristina, near the top of the landslip covering the southeast side of Pizza Cuecena. This fossil fish is the first one to be found in the Italian Werfenian, and it is one of the few known from strata of that age in continental Europe. It is preserved in impure limestone, and it consists of part and counterpart of the head, most of the body, and the dorsal fin. The fossil lacks the anal area, the entire caudal area, and small peripheral portions of the dorsal and ventral regions. The head bones are partially visible, and they, together with numerous blue-black scales, cover the body and are prominent.

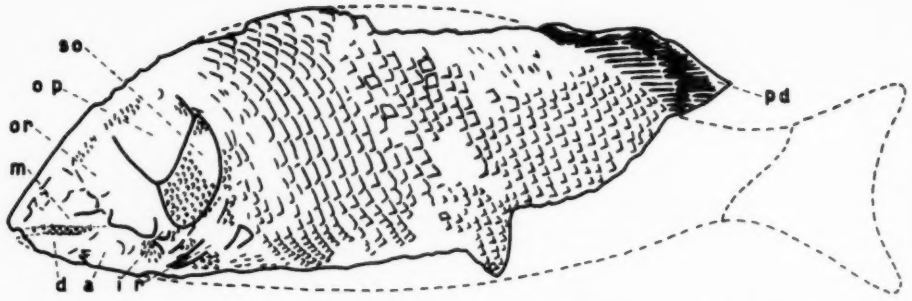
Both the right and left sides of the fish were compressed together during preservation, and on the two parts of the fossil the external or internal surfaces of bones and scales appear. The curvature of the specimen is secondary and has no significance.

The fossil under consideration is, on the whole, well preserved and is one of the best specimens of the European Werfenian ichthyofauna. In Text-figure 1, the writer united by superposition of two drawings, the details seen on both parts of the specimen, and the limits of the missing portions have been restored by dotted lines. These limits have been drawn according to data from comparisons with many figures of Triassic holosteans. The shape of the tail varies considerably in this group. My restoration should, therefore, be considered quite theoretical. It is also impossible to ascertain, even approximately, the correct position and the shape of the fins on the lower margin.

The outline of the body is thick, with a very high back; the structure of the head shows a marked resemblance to the fish of

## EXPLANATION OF PLATE 46

FIG. *1-5*—*Archaeolepidotus leonardii* Accordi, n. gen., n. sp.; holotype, from the lower Werfenian of Mount Pic, Gardena Valley, Dolomite Alps, Italy. *1,2*, counterpart and part of entire specimen, ×1; *3*, suboperculum, with anterior border to the left, ×3; *4*, dorsal fin, showing first pennate ray ($r_1$) protected by two fulcra (f) and by a basal scale (s), ×2; *5*, thin section of part of a dorsal scale, ×40.




TEXT-FIG. 1—Reconstruction of *Archaeolepidotus leonardii*, n. gen., n. sp.; the solid lines show the details visible on both the part and the counterpart reunited; the dotted lines are theoretical. *a* = angular; *d* = dental; *i* = interoperculum; *m* = maxillar; *op* = operculum; *or* = orbit; *pd* = dorsal fin; *r* = branchiostegal rays; *so* = suboperculum; ×0.85.

the Middle and Upper Triassic, and little affinity with Permian forms, although the specimen being described lived shortly after the close of the Paleozoic. The dorsal fin is characteristic, owing to its posterior position. The surface of the body is covered with a large number of small smooth scales that are for the most part rhomboidal, though their shape varies according to the position on the body.

SYSTEMATIC PALEONTOLOGY

Family SEMIONOTIDAE

ARCHAEOLEPIDOTUS LEONARDII, n. gen., n. sp.

Pl. 46, fig. 1–5

*Structure of the head.*—The head (Text-fig. 1) is of massive shape, slightly pointed, and characterized by an outline (from the supratemporal to the tip of the muzzle) which follows a very sloping line, almost straight, and longer than in other similar specimens. Therefore the skull assumes a remarkable height. The preserved bones, or those recognizable, are the following: the operculum, the suboperculum, the preoperculum, the jaw, and parts of the nasal and dental regions. Also, data can be assumed about other bones, both of the skull and the neck. In the mouth there can be seen some small teeth of the upper and lower marginal series.

The operculum is of a reduced height, compared with those of most holosteans of the Middle and Upper Triassic. This fact agrees with the age of the fish in question, because generally Neotriassic and Jurassic forms have more highly developed opercular bones than do those of the Permian. Although the upper margin of the operculum is not visible, the general form of the bone is trapezoidal, and the inferior edge slopes strongly forward; the antero-inferior and postero-inferior angles are slightly blunted. The opercular bone appears for the most part to be smooth. However, it must have had a vermicular ornamentation as can be deduced from a small portion of the external surface preserved on one of the two parts.

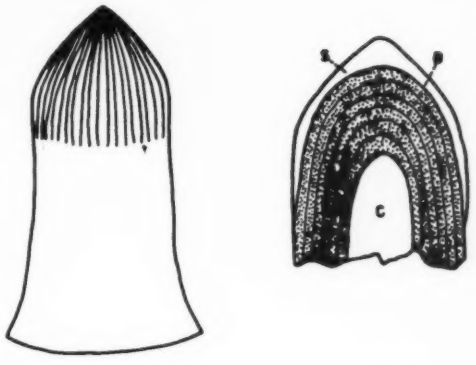
The suboperculum is highly developed, and it has a large posterior outline and a round inferior edge. On the anterior side it is clearly limited by the operculum, and near the limit of the latter it presents an elevated edge. It is a strong and very high bone, higher than the suboperculum of all known semionotids. Its surface (excluding only the higher anterior edge) is adorned with small regular semilunar plates (Pl. 43, fig. 3) the convexity of which is in the caudal direction. These small plates are not all of the same shape and size; they are oblique and do not overlap. The inner surface of the suboperculum is smooth.

The shape, the size, and the relationship between the operculum and the suboperculum, as well as the disposition of the inner operculum, are the most important elements, indicating that *Archaeolepidotus leonardii* is close to the group of the Parasemionotidae of the Lower Triassic of Madagascar. (The specific name of the new form is in honor or Professor Piero Leonardi, an authority on the geology of the Dolomite Alps.)

Only the posterior limit of the preopercu-

lum is visible. In spite of the few data available, it can be deduced that the longest axis (height) of the preoperculum is subvertical, whereas most of the species of holosteans and subholosteans have a curved preoperculum, which slopes from the top toward the dental region. The line of the interoperculum, of which only the inferior edge can be seen, is important (Text-fig. 1). The space left free by the surrounding bones indicates that the interoperculum is short and subtriangular. The position of this tiny bone, in addition to the shape of the operculum and suboperculum, suggests a relationship between our new genus and some of the representatives of the Parasemionotidae from the Eotrias of Madagascar.

Little can be said about the supratemporal, frontal, nasal, and premaxillary bones. The characteristic setting of these bones, all on almost a straight line, gives *Archaeolepidotus* a long sloping outline. The limits of the maxilla are not very definite. Careful examination failed to reveal clearly whether or not the large bony plaque, located between the teeth and the suboperculum, belongs to the maxilla. The jaw bears 18 small teeth, which have been somewhat misplaced from their original position. Other small teeth (16 in number) are set along the mandible, which appears to be a little shortened in proportion to the other head bones. Two small lines, just above two detached teeth and left of the interior edge of the mandible (Text-fig. 1), may indicate the dividing line between the dental and angular regions. The teeth, visible only under a lens, are very small, and all belong to the external set. Altogether, there are 36 teeth; 18 belong to the upper series and 16 to the lower; and two (probably belonging to the lower series) are no longer in their original position and are preserved under the dental region. They are all cylindrical, broadened at the base, and crowned by a terminal portion with a pointed apex of a different color. The basal part of the tooth is dark gray, the distal portion is brown, and the apex is transluscent milky-white, due to the strong development of enamel. The base of the tooth is smooth, but the upper part bears fine longitudinal striae visible only under a microscope. The external profile of the teeth is intermediate between that of




*A* *B*

TEXT-FIG. 2—*A*, exterior view of a marginal tooth, ×50. *B*, structure of the apical part of the same; *c* = pulp cavity; *d* = dark dentine with low birefringence and growth lines; *s* = enamel, transparent and highly birefringent, limited to the distal part of the tooth; ×63.

*Saurichthys* and that of *Serrolepis*, but the ornamentation is like that of the latter genus, though the longitudinal striae are more numerous and less evident. In longitudinal section, the tooth can be seen to consist of a dental cavity, dentine, and enamel. The dental cavity is long and thin. It is similar to the general shape of the tooth and is filled with transparent calcite (epigenetic). The dentine is a brown mass, friable, bitmunious, and with very low birefringence. Its apex is blunt. The enamel is transluscent with very strong birefringence, and it covers only the upper part of the tooth. At the apex, it is strongly developed, but it becomes progressively thinner toward the collar and gradually disappears.

The shape of the orbit is uncertain. On the fossil, only the interior part of the outline is indicated, but it can be discerned that there is a slight hollow higher than long. Therefore, it seems that a horizontally elongate orbit (as in *Heterolepidotus* and *Colobodus*) was not present, but it may be that the outline was subcircular as in *Paralepidotus*, or that it was higher than long. The clavicular region is poorly preserved and is covered with scale-prints. Therefore, nothing definite can be ascertained as to the shape or the disposition of the clavicular bone complex. The two wedge-shaped bones sketched under the

suboperculum are believed to be branchiostegal rays. Of particular interest are a group of small flat triangular-pointed scales under the suboperculum in the region of the branchiostegal rays. They are within a triangular area and are not present in most fossil fish. However comparable bones are visible in a specimen of *Dapedius* illustrated by Smith Woodward and in a *Heterolepidotus* from Besano, Italy (Brough, 1939, p. 37, Text-fig. 34).

*Description of the trunk.*—Although the ventral line cannot be accurately traced, it can be seen that the trunk (Text-fig. 1) has a short, thick, gibbous aspect. All attempts to unite the outline of the head end and the postero-superior portion resulted in a very high, curved, dorsal margin.

The general aspect of the trunk, the position of the dorsal fin, the shape of the scales, the structure of some of the head bones, all reveal a relationship between our specimen and certain species of the African Triassic (see the memoirs of Piveteau and of Lehman on the Parasemionotidae of the Lower Triassic of Madagascar, and the publications of Smith Woodward and of Schellwien on somewhat younger forms from the Upper Triassic of South Africa). The general shape of the trunk, the structure of the dorsal fin, and the size and arrangement of the scales indicate that *Archaeolepidotus* is like many other holosteans of the Alpine Middle Triassic. The genus seems to be transitional between a small group of subholosteans of the African Eotrias and certain later Triassic holosteans well represented in the Alps.

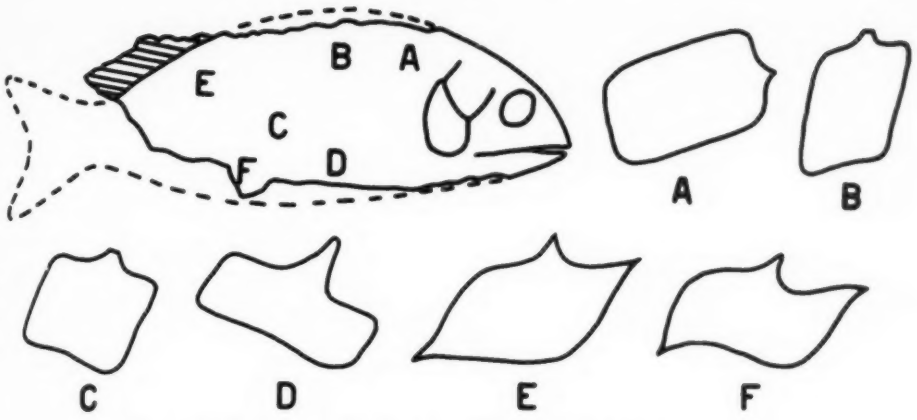
The scales, which are small, thick and strong, are preserved almost all over the trunk. They are of rhomboidal and rectangular shape and are arranged in slightly curved series with an average deviation of some 20° in the anterior region and about 5° in the posterior. They have a fairly smooth surface but in some cases are marked by small pores. The posterior border of the scales are not saw-toothed. The number of scales in a vertical series cannot be accurately determined. There are about 18–20 on the anterior part of the trunk, 23–25 near the top of the back, and 12–16 on the posterior part. The number of vertical series appears to have been about 40.

The shape and orientation of the scales varies both longitudinally and transversely. On the outside, they all appear to have a rhomboidal or a lozenge-shaped outline, but this aspect is due to their overlapping arrangement. In the middle of the upper edge, they all have an articulating spine which extends beneath the preceding scale. Each scale has, in turn, on the inner surface a corresponding furrow in which the spine of the following ventral scale fits. It is possible to reconstruct the shape of the different scales because the outer surfaces of the left-side scales and the inner surfaces of the right-side scales are visible. The invariable presence of a spine of articulation is one of the most distinctive characters of our fossil. This specimen is important because it represents a rare form from a stratigraphic position in which fish are not common and because it reveals characters ordinarily not ascertainable. For example, the outline of isolated scales can in many cases be seen clearly, but on a strongly compressed fossil fish where the scales are *in situ* and are somewhat overlapped, they may appear rhomboidal even though they are of a different shape.

Text-figure 3 elucidates the shape of the scales in the different parts of the trunk. On the whole, there is a greater difference between the scales of the thoracic region and those of the caudal part than between the dorsal and ventral scales. These characteristics help to distinguish *Archaeolepidotus* from other similar genera.

The structure of the scales is rather simple. Thin sections show that: (1) the scales consist of only one basal layer and only one ganoine (enamel) covering (Pl. 46, fig. 5); (2) the basal layer is homogeneous, is dark brown, has a very low birefringence, and is only faintly striate; and (3) the enamel forms a relatively thick layer. The enamel is strongly birefringent and under cross-Nicols it appears to be composed of fine prisms set with the long axis normal to the surface. This material covers the entire scale, and it is thicker medianly than laterally.

The preserved part of the dorsal fin has very distinct characteristics, which, however, are similar to those of *Paralepidotus*. This fin is located posteriorly. On it 14 rays are preserved, all strong, much inclined, al-




TEXT-FIG. 3—Form of the scales in the different parts of the trunk, ×6. The position of the scales is indicated on the outline.

most horizontal, and separated from one another by a distance a little greater than their diameter. Near their mid-length the rays branch and each of the two branches continues parallel. Each ray is subdivided into segments which are long at the base and become progressively shorter distally. Toward the terminus of the rays, the segments are shorter than wide. Two or three of the longest rays seem to be preserved in their entirety, and they are about 17 mm. in length. At the point of attachment of each ray there is a small short spine which is directed dorsally. In the fossil it can be seen that the fin does not begin at the top of the back but from a more posterior position. The initial part is much like *Lepidotus*. First there is a strong pointed and triangular basal scale much like a fulcrum. Then two massive fulcra follow (the second one is thinner and longer); they are curved and lie upon the first ray which is distinctly feathered only toward the outside. Then the other 13 rays, which are all alike, develop. As Boni (1937) noted, in *Paralepidotus*, the first undivided half of each ray seems to be composed of a strong and a thin element fused longitudinally.

MEASUREMENTS

| | |
|---|---|
| Presumptive length of the fish from the apex of the muzzle to the terminus of the tail | 154 mm. |
| Length of the head, from the apex of the muzzle to the posterior edge of the subopercu-lum | 40 mm. |
| Presumptive height taken at the maximum point of the curve on the back | 59 mm. |
| Height and width of the scales of the antero-median region. | 4.3×2.8 mm. |
| Height and width of the scales of the postero-median region | 3.0×2.7 mm. |
| Average height of the marginal teeth | 0.60 mm. |
| Average diameter of the marginal teeth | 0.28 mm. |

SYSTEMATIC POSITION AND COMPARISONS

*Definition of the genus.*—The new genus *Archaeolepidotus* has the following characteristics: Medium-sized oval body (15 cm. long) with high and gibbous back, subtriangular short and thick head, and a very long and inclined upper outline. The operculum is reduced and is trapezoidal with an angular outline and vermicular ornamentation; the suboperculum, which is high and is as well developed as is the operculum, has rounded edges and an ornamentation of semilunar plates; the preoperculum is poorly defined in the specimen but it is set with a subvertical axis; the interoperculum is modest in size and is subtriangular. Marginal teeth are small, pointed, cylindrical-conical, with slight longitudinal streaks limited to their distal parts and having a simple structure (dentine partly covered with enamel). The area of the branchiostegal rays is covered with triangular plates; the scales of the trunk are small and thick, varying in shape according to the position; they have an articulating spine, smooth margins, and a simple structure with a basal layer covered

with thick ganoine. The dorsal fin is located posteriorly, and it has rays which branch near their mid-length. The rays are separated from one another by spaces as wide as their thickness. They are divided into numerous segments which distally become progressively shorter, and they seem to be formed by the fusion of a strong element and a thin one. The dorsal fin begins with a feathered ray and is protected by two strong fulcra and by a basal scale.

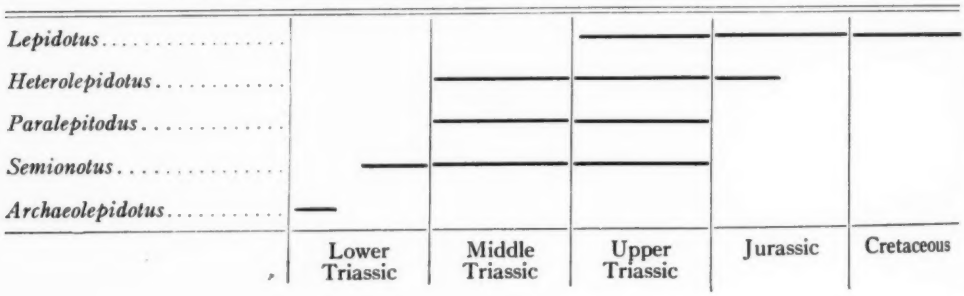
The specimen found in Val Gardena presents many characters which indicate a relationship to several holostean or subholostean genera, especially to those of the Semionotidae and the Parasemionotidae. The nature and the measurements of the operculum, the suboperculum and the interoperculum, the general shape of the body, and the position of the dorsal fin are reminiscent of some species of the Eotrias of Madagascar included in the last of the above-named families. However, there are fundamental differences in morphology and structure between *Archaeolepidotus* and the coeval African group. Nevertheless, both probably had a common origin.

As to the relationship between *Archaeolepidotus* and the holosteans of the Middle and Upper Triassic of Europe (rarely in the Lower Triassic) comparisons should be made with *Heterolepidotus*, *Paralepidotus*, *Semionotus*, and *Lepidotus*. *Heterolepidotus* has the following characters in common with *Archaeolepidotus:* the dimension of the body, the ornamentation of the head-bones, the remarkable development (in some species) of the suboperculum, the external shape of the teeth, and the covering of the branchiostegal region with small scales noted in some species. However, it differs from the fish found in Val Gardena in important characters, for example: the more slender shape, thinner head, more oblong orbit, smooth marginal teeth, and saw-tooth scales.

Relationships can also be noted between our specimen and *Paralepidotus*, a genus founded by Stolley for those forms intermediate between *Lepidotus* and *Colobodus* and, according to Stolley, characteristic of the Middle and Upper Triassic of the Alps and similar to *Heterolepidotus*. The resemblances consist of: the general shape—a high back, and a short, thick body; the orbit which is not oblong; in the measurement and disposition of the scales without any superficial ornamentation; and in the structure of the rays of the fin. The chief differences between the two genera are: the measurements of the fish—*Paralepidotus* is on the average three times as long; the shape of the suboperculum—in *P.* it is low and broad and has an anterior spiny process near the top; the marginal teeth—which in *P.* are smooth, with different shape and structure; and the scales which seem to be more homogenous in outline, have no articulating spine, and are slightly saw-toothed in the pectoral region.

Some general characters (the shape of the body, the structure of some head-bones, the shape and disposition of the scales, the posterior location of the dorsal fin, and the series of pointed marginal teeth) indicate a relationship between the new genus and *Semionotus*, which is found especially in the German Triassic—not only in the Middle and Upper Triassic but also in the Werfenian. Our specimen is also related to

TABLE 1.—KNOWN DISTRIBUTION OF RELATED HOLOSTEAN GENERA



*Lepidotus*, which is younger, but the differences between these two genera are great and the relationship is not close.

In conclusion, I wish to emphasize the surprisingly great age of the new genus, *Archaeolepidotus*, the type of which came from near the boundary between the Permian and the Triassic. The Malagasian ichthyofauna belongs to the middle Werfenian, and most of the European genera with which it has analogies did not arise until later. The geological distribution of the European genera with similarities is shown on Table 1.

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# BIBLIOGRAPHY AND INDEX TO NEW GENERA, SPECIES, AND VARIETIES OF FORAMINIFERA FOR THE YEAR 1954

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ABSTRACT—The following bibliography lists a total of 517 papers dealing exclusively or partly with Foraminifera. Of this total 420 titles refer to the year 1954. One paper is added for 1944, one for 1945, 5 for 1950, 4 for 1951, 10 for 1952, and 76 for 1953.

The Index cites as new foraminiferal taxa erected in 1954: 1 superfamily, 1 family, 3 subfamilies, 28 genera, 2 subgenera, 377 species, 58 varieties (subspecies), 12 new names, 11 homonyms, 39 nomina nuda, and 241 forms to which the open nomenclature was applied. Supplemented are for previous years: 1 variety for 1948; 1 genus for 1950; 1 genus and 2 species for 1951; 1 subfamily, 1 genus, 38 species, 6 varieties, 3 homonyms and 6 nomina aperta for 1952; 3 families, 7 genera, 62 species, 9 varieties, 3 homonyms and 46 nomina aperta for 1953. Publications listed in the Bibliography under Nr. 397, 423, 424, 425, 426, 428, 433, 450, 451, and 491, not available to the compiler, apparently include more new Foraminifera erected between 1950 and 1954.

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BROTZENIA nov. gen. Hofker, **191,** p. 169. New genus of the family Epistomariidae. Genotype: *Epistomina spinulifera* Reuss, 1862, Sitzber. Akad. Wiss. Wien, math.-nat. Cl., vol. 46, p. 93, pl. 13, fig. 4–7. Middle Jurassic to Lower Cretaceous.

—— *parastelligera* Hofker, **191,** p. 180, text fig. 4–6. Upper Dogger, Germany. For: *Epistomina stelligera* (Ruess) in Bartenstein, and Brand, 1937, Abhandl. Senckenberg. Naturf. Ges., vol. 439, p. 191, pl. 11–a, fig. 21 etc.

*Bulimina thanetensis* Cushman and F. L. Parker, 1947, var. *hengisti* Haynes, **184,** p. 188, text fig. 7,8. Paleocene, England.

—— *wyomingensis* Fox, **142,** p. 118, pl. 26, fig. 8–11. Cretaceous S. Dakota and Wyoming.

*Buliminella apenninica* Emiliani, **126,** p. 113, pl. 21, fig. 12. Oligocene, Italy.

—— *isabelleana* Camacho, **65,** p. 33, pl. 6, fig. 19. Upper Cretaceous, Argentina.

*Calcarina delicata* Todd and Post, **380,** p. 563, pl. 201, fig. 5,6. Plio-Pleistocene, Bikini.
—— *rustica* Todd and Post, **380,** p. 563, pl. 201, fig. 7. Upper Miocene, Bikini.
*Cassidulina gemma* Todd, **94,** p. 366, pl. 90, fig. 26,27. Recent, Marshall Islands.
—— *marshallana* Todd, **94,** p. 366, pl. 90, fig. 28,29. Recent, Marshall Islands.
*Ceratobulimina* (*Ceratolamarckina*) *jutlandica*, Troelsen, **390,** p. 456, pl. 10, fig. 7–9. Paleocene, Denmark.
CERATOLAMARCKINA subgen. nov. Troelsen, **390,** p. 454. New subgenus of *Ceratobulimina* Toula, 1915. Family Ceratobuliminidae. Subgenotype: *Ceratobulimina woodi* Khan, 1950, Jour. R. Micr. Soc. London, (3), vol. 70, p. 276, pl. 2, fig. 16,20,21. Middle Cretaceous; Paleocene.
CHITINOSIPHON gen. nov. Thalmann and Bermudez, **372,** p. 53. New genus of the family Rhizamminidae. Genotype: *Chitinospihon rufescens* Thalmann and Bermudez, 1954, *ut infra*. Recent, off Cuba.
—— *rufescens* Thalmann and Bermudez, **372,** p. 53, text fig. 1–4. Recent, off Cuba, 1600–1800 fathoms.
*Cibicides americanus* (Cushman, 1918) var. *paraensis* Petri, **309,** p. 135, pl. 14, fig. 2–4, Miocene, Brazil.
—— *basraensis* Rey, **335,** p. 211, pl. 12, fig. 7. Oligocene, Morocco (published January 1955).
—— *cururuensis* Petri, **309,** p. 136, pl. 14, fig. 5–7. Miocene, Brazil.
—— *daguerri* Neumann, **290,** p. 113, text fig. A–C. Upper Lutetian, France.
—— *globosus* Camacho, **65,** p. 34, pl. 6, fig. 16. Upper Cretaceous, Argentina.
—— *hedbergi* Petters, **310,** p. 40, pl. 8, fig. 11. Campanian, Colombia.
—— *micrus* (Bermudez, 1949) var. *pusillus* Proto Decima and Ferasin, **324,** p. 250, pl. 11, fig. 6,7. Upper Eocene, Italy.
—— *protuberans* F. L. Parker, **305,** p. 542, pl. 12, fig. 13,14,16. Recent, Gulf of Mexico, 155 m.
—— *superbus* Camacho, **65,** p. 34, pl. 6, fig. 18. Upper Cretaceous, Argentina.
—— *tani* Iwasa and Kikuchi, **213,** p. 193, text fig. 8. Miocene, Japan.
*Codonofusiella cuniculata* Kanmera, **217,** p. 6, pl. 3, fig. 12,14–19. Upper Permian, Japan.
CORROSINA gen. nov. Nyirö, **295,** p. 68. New genus of the family Heterohelicidae. Genotype: *Corrosina pupoides* Nyirö, 1954, *ut infra*. Oligocene.
—— *pupoides* Nyirö, **295,** p. 69. Figured (publication not seen by compiler). Chattian, Hungary.
*Cribroelphidium chaputi* Tintant, **375,** p. 195, pl. 2, fig. 3. Pliocene, Turkey: Pleistocene, France.
*Conorbis*, see *Eponides*
*Cyclammina apenninica* Emiliani, **126,** p. 117, pl. 21, fig. 18,19. Oligocene, Italy.
*Darbyella argentinensis* Boltovskoy, **45,** p. 144, pl. 9, fig. 1–3. Recent, Gulf of San Jorge, Argentina
—— *mimounaensis* Rey, **335,** p. 210, pl. 12, fig. 5. Bartonian, Morocco (published January 1955).
DAVIESINA gen. nov. Smout, **355,** p. 66. New genus of the family Rotaliidae. Genotype: *Daviesina khatiyahi* Smout, 1954, *ut infra*. Paleocene.
—— *danieli* Smout, **355,** p. 69, pl. 7, fig. 15–17. Paleocene, Qatar.
—— *khatiyahi* Smout, **355,** p. 67, pl. 12, fig. 1–11; pl. 14, fig. 7. Paleocene, Qatar.
—— *langhami* Smout, **355,** p. 68, pl. 11, fig. 1–11. Paleocene, Qatar.
*Dentalina astrae* Camacho, **65,** p. 33, pl. 6, fig. 15. Upper Cretaceous, Argentina.
—— *bighornensis* Fox, **142,** p. 116, pl. 25 (not pl. 2). Cretaceous S. Dakota and Wyoming.
—— *cineraria* Emiliani, **126,** p. 119, pl. 22, fig. 4. Oligocene, Italy.
—— *sherborni* Bowen, **51,** p. 145, pl. A, fig. 9. Eocene, London Clay, England. For: *Vaginulina legumen* (Linne) in Sherborn and Chapman, 1886, Jour. R. Micr. Soc., London, (2), vol. 6, p. 753, pl. 15, fig. 19.
DICTYOKATHINA gen. nov., Smout, **355,** p. 64. New genus of the family Rotaliidae. Genotype: *Dictyokathina simplex* Smout, 1954, *ut infra*. Paleocene.
—— *simplex* Smout, **335,** p. 65, pl. 8, fig. 1–11. Paleocene, Qatar.
DISCORBIDEA new superfamily, Smout, **355,** p. 81, Includes the families: Discorbidae, Amphisteginidae, Cymbaloporidae, Planorbulinidae and probably also Globorotaliidae.
*"Discorbis" bulbosa* F. L. Parker, **305,** p. 523, pl. 8, fig. 10–12. Recent, Gulf of Mexico, 100–205 m.
*Discorbis chapmani* Bowen, **51,** p. 164, pl. C, fig. 14,15. Eocene, London Clay, England. For: *Discorbis rosacea* (Orbigny) in Sherborn and Chapman, 1886, Jour. R. Micr. Soc. London, (2), vol. 6, p. 756, pl. 16, fig. 11.
—— *laddi* Kleinpell, **225,** p. 57, pl. 5, fig. 4,5. Neogene, Fiji.
—— *luciferus* Camacho, **65,** p. 34, pl. 6, fig. 10. Upper Cretaceous, Argentina.
—— (*Lamellodiscorbis*) *magna* Vialli, 1951, var. *aquitanica* Neumann and Boulanger, **292,** p. 114, text fig. 2. Lower Lutetian, France.
*Dorothia vulsa* Emiliani, **126,** p. 120, pl. 22, fig. 9. Oligocene, Italy. For: *Dorothia conula* Cushman, 1937, Cushman Lab. Foram. Res., Spec. Pap. 8, p. 76, pl. 8, fig. 15–17 (*non* fig. 11–14).
*Dunbarinella americana*, Thompson, **373,** p. 45, pl. 16, fig. 16–24; pl. 17, fig. 1–6. Wolfcampian, Kansas.
—— *eoextenta* Thompson, **373,** p. 46, pl. 16, fig. 25; pl. 17, fig. 7–20; pl. 18, fig. 1–16; pl. 23, fig. 16. Wolfcampian, Kansas.
—— *extenta* Thompson, **373,** p. 47, pl. 19, fig. 1–6. Wolfcampian, Texas.
—— *fivensis* Thompson, **373,** p. 44, pl. 16, fig. 4–15. Wolfcampian, Kansas.
—— *glenensis* Thompson, **373,** p. 48, pl. 18, fig. 17,18; pl. 20, fig. 1–16. Wolfcampian, Kansas and New Mexico.
—— *hughesensis* Thompson, **373,** p. 48, pl. 7, fig. 14–17; pl. 19, fig. 7–16. Wolfcampian, Kansas, New Mexico and Utah.
—— *wetherensis* Thompson, **373,** p. 49, pl. 23, figs. 5–14. Wolfcampian, Texas.

*Eggerella mystica* Emiliani, **126,** p. 121, pl. 22, fig. 10,11. Oligocene, Italy.

—— *pulcherella* Proto Decima and Ferasin, **324,** p. 248, pl. 11, fig. 1. Upper Eocene, Italy.

*Ehrenbergina insueta* Proto Decima and Ferasin, **324,** p. 249, text fig. 1. Eocene, Italy.

ELLIPSOIDININAE new subfam. Petters, **310,** p. 39. New subfamily of family Ellipsoidinidae. Includes the genera: *Pleurostomella* Reuss, 1860; *Pleurostomellina* Schubert, 1911; *Ellipsopleurostomella* Silvestri, 1903; *Ellipsobulimina* Silvestri, 1903; *Ellipsoidina* Seguenza, 1859, and probably also *Dentalinoides* Marie, 1941, *Pinarina* Bermudez, 1937, *Gonatosphaera* Guppy, 1894, and *Parafissurina* Parr, 1947.

*Ellipsonodosaria ugoensis* Iwasa and Kikuchi, **213,** p. 192, text fig. 5. Miocene, Japan.

*Elphidium advena* (Cushman, 1922) var. *dispar* Cushman, **94,** p. 346, pl. 86, fig. 31. Recent, Marshall Islands.

—— *marshallanum* Todd and Post, **380,** p. 556, pl. 198, fig. 13. Lower Miocene, Bikini.

—— *morenoi* Bermudez, 1935, subsp. *ameghinoi* Boltovskoy, **46,** p. 277, pl. 25, fig. 1,2. Recent, Bay of San Jorge, Argentina.

—— *paraensis* Petri, **309,** p. 77, pl. 5, fig. 5,6. Miocene, Brazil.

—— cf. *poeyanum* (Orbigny, 1839) var. *elongata* Petri, **309,** p. 79, pl. 5, figs. 9,10. Miocene, Brazil.

—— *sagrai* (Orbigny, 1839) var. *cururuensis* Petri, **309,** p. 80, pl. 5, fig. 13–16. Miocene, Brazil.

—— *tropicalis* Petri, **309,** p. 81, pl. 5, fig. 17,18. Miocene, Brazil.

*Elphidium (?) ellisi* Weiss, **407,** p. 159, pl. 32, fig. 5,6. Pleistocene, New York, U.S.A.

—— *(?) limbatus* Petri, **309,** p. 75, pl. 5, fig. 1,2. Miocene, Brazil, (*Note:* Preoccupied by *Elphidium macella* (Fichtel and Moll) var. *limbatum* (Chapman, 1907), Jour. Queckett Micr. Club, (2), vol. 10, p. 142, pl. 10, fig. 9; re-named: *Elphidium (?) toddae* Petri, 1955).

*Entosolenia orbignyana* (Seguenza, 1862), var. *miocenica* Ferasin, **133,** (publication not seen by compiler), illustr., Miocene, Italy.

EPISTOMARIIDAE new family Hofker, **191,** p. 166. Includes the genera *Epistomaria* Galloway, 1933; *Epistominoides* Plummer, 1934; *Höglundina* Brotzen, 1948; *Brotzenia* Hofker, 1954, *ut supra; Voorthuysenia* Hofker, 1954, *ut infra,* and *Hiltermannia* Hofker, 1954, *ut infra.*

*Epistomina hoffmeisteri* Kleinpell, **225,** p. 62, pl. 5, fig. 8. Neogene, Fiji.

—— *nuda* Terquem, 1883, var. *vulgaris* Bielecka and Pozaryski, **37,** p. 199, pl. fig. 59. Upper Malm, Poland.

—— *stellicostata* Bielecka and Pozaryski, **37,** p. 71, pl. 12, fig. 60. Upper Malm, Poland.

———— var. *granulosa* Bielecka and Pozaryski, **37,** p. 72, pl. 12, fig. 61. Upper Malm, Poland.

*Epistominoides danica* Troelsen, **390,** p. 461, pl. 11, fig. 1–3. Paleocene, Denmark.

*Eponides gaviotaensis* Wilson, **412,** p. 143, pl. 16, fig. 11,12. Oligocene (Refugian), California.

—— *hatakeyamai* Iwasa and Kikuchi, **213,** p. 192, text fig. 6. Miocene, Japan.

—— *marcida* Emiliani, **126,** p. 124, pl. 22, fig. 24. Oligocene, Italy. For: *Gyroidina jarvisi* Cushman and Stainforth in Cushman and Renz, 1948, Cushman Lab. Foram. Res., Spec. Publ. 24, p. 34, pl. 7, fig. 4, 5.

—— *perspicax* Camacho, **65,** p. 34, pl. 6, fig. 20. Upper Cretaceous, Argentina.

—— *peruvianas* (Orbigny, 1839) var. *campsi* Boltovskoy, **45,** p. 205, pl. 17, fig. 6–8. Recent, Gulf of San Jorge, Argentina.

—— *shoshonensis* Fox, **142,** p. 119, pl. 26, fig. 12–14. Cretaceous S. Dakota and Wyoming.

*Eponides (Conorbis) polonicus* Bielecka and Pozaryski, **37,** p. 70, pl. 12, fig. 58. Upper Malm, Poland.

*Eulepidina* see *Lepidocyclina*

FALLOTELLA gen. nov. Mangin, **255,** p. 209. New genus of the family Orbitolinidae. Genotype: *Fallotella alavensis* Mangin, 1954, *ut infra.* Paleocene.

—— *alavensis* Mangin, **255,** p. 209, text fig. 1,2. Paleocene, Spain.

*Fissurina circularis* Todd, **94,** p. 351, pl. 87, fig. 27. Recent, Marshall Islands. (For synonymy: see original paper).

—— *millettii* Todd, **94,** p. 351, pl. 87, fig. 30. Recent, Marshall Islands. (For synonymy see original paper).

*Flabellammina bessboroensis* Stelck and Wall, **361,** p. 19, pl. 1, fig. 26. Upper Cretaceous, Western Canada.

—— *gleddiei* Stelck and Wall, **361,** p. 20, pl. 1, fig. 24,25; pl. 2, fig. 16. Upper Cretaceous, Western Canada.

—— *hendersonensis* Stelck and Wall, **361,** p. 20, pl. 2, fig. 17,18. Upper Cretaceous, Western Canada.

—— *succedens* Stelck and Wall, **361,** p. 21, pl. 1, fig. 23. Upper Cretaceous, Western Canada.

FLABELLAMMINOPSIS gen. nov. Malecki, **252,** p. 104. Family not stated: (Lituolidae) Genotype: *Flabellamminopsis variabilis* Malecki, 1954, *ut infra.* Middle Jurassic (Dogger).

—— *corrugatus* Malecki, **252,** p. 107, pl. 3, fig. 5; pl. 4, fig. 16. Dogger, Poland.

—— *crassus* Malecki, **252,** p. 107, pl. 3, fig. 1; pl. 4, fig. 14,15. Dogger, Poland.

—— *diversiformis* Malecki, **252,** p. 110, pl. 3, fig. 7; pl. 5, fig. 14. Dogger, Poland.

—— *planulatus* Malecki, **252,** p. 104, pl. 3, fig. 8; pl. 4, fig. 1–3. Dogger, Poland.

—— *proteus* Malecki, **252,** p. 108, pl. 3, fig. 4; pl. 5, fig. 7,10. Dogger, Poland.

—— *tetracarinatus* Malecki, **252,** p. 109, pl. 3, fig. 2; pl. 5, fig. 8,12,13. Dogger, Poland.

—— *tricarinatus* Malecki, **252,** p. 107, pl. 3, fig. 6; pl. 5, fig. 2,3. Dogger, Poland.

—— *turbidus* Malecki, **252,** p. 108, pl. 3, fig. 9; pl. 4, fig. 12; pl. 5, fig. 9. Dogger, Poland.

—— *variabilis* Malecki, **252,** p. 105, pl. 4, fig. 4,7,8; pl. 3, fig. 4; text fig. 2. Dogger, Poland.

*Frankeina kimeridensis* Bielecka and Pozaryski, **37,** p. 29, pl. 3, fig. 8. Upper Malm, Poland.

*Frondicularia greybullensis* Fox, **142,** p. 118, pl. 26, fig. 4–6. Cretaceous S. Dakota, Wyoming.

—— *superbissima* Camacho, **65,** p. 33, pl. 6, fig. 11. Upper Cretaceous, Argentina.
*Fusulina attentuata* Alexander, **7,** p. 23, pl. 1, fig. 12–15. Middle Pennsylvanian, Oklahoma.
—— *equabilis* Alexander, **7,** p. 24, pl. 2, fig. 1–4. Middle Pennsylvanian, Oklahoma.
—— *equilaqueata* Alexander, **7,** p. 26, pl. 1, fig. 16–19. Middle Pennsylvanian, Oklahoma.
—— *expedita* Alexander, **7,** p. 27, pl. 2, fig. 5–8. Middle Pennsylvanian, Oklahoma.
—— *occultifons* Alexander, **7,** p. 40, pl. 4, fig. 1–4. Middle Pennsylvanian, Oklahoma.
—— *plena* Alexander, **7,** p. 41, pl. 4, fig. 5–8. Middle Pennsylvanian, Oklahoma.
—— *tumida* Alexander, **7,** p. 43, pl. 4, fig. 9–12. Middle Pennsylvanian, Oklahoma.
*Fusulinella haymondensis* Skinner and Wilde, **351,** p. 801, pl. 96, fig. 8–15. Early Pennsylvanian, Texas (published January 1955).
—— *texana* Skinner and Wilde, **351,** p. 800, pl. 96, fig. 3–7. Early Pennsylvanian, Texas (published January 1955).
—— *thompsoni* Skinner and Wilde, **351,** p. 797, pl. 95, fig. 7–12; pl. 96, fig. 1–2. Early Pennsylvanian, Texas (published January 1955).
GANELLA gen. nov. Aurouze and Boulanger, **23,** p. 187. New genus of the family Anomalinidae, subfamily Planulininae. Genotype: *Ganella neumannae* Aurouze and Boulanger, 1954, *ut infra*. Ypresian.
—— *neumannae* Aurouze and Boulanger, **23,** p. 187, text fig. 1–3. Ypresian, France.
*Gaudryina cobbani* Fox, **142,** p. 112, pl. 24, fig. 10. Cretaceous S. Dakota and Wyoming.
—— *haysakai* Chang, **70,** p. 106, pl. 1, fig. 9–15. Lower Oligocene, Taiwan.
—— *trullisata* Todd, **94,** p. 331, pl. 83, fig. 15. Recent, Marshall Islands.
*Gaudryina* (*Gaudryina*) *ashfordi* Bowen, **51,** p. 167, pl. D, fig. 4,5. Eocene, London Clay, England. For: *Gaudryina pupoides* Orbigny in Sherborn and Chapman, 1886, Jour. R. Micr. Soc. London, (2), vol. 6, p. 743, pl. 14, fig. 7.
—— (*Pseudogaudryina*) *kokuseiensis* Chang, **71,** p. 59, pl. 1, fig. 1–6. Miocene, Taiwan.
*Gaudryinella schröderi* Hagn, **169,** p. 15, pl. 3, fig. 1–4; pl. 4, fig. 3,4. Eocene, Bavaria, Germany.
GEMELLIDES subgen. nov. Vassilenko, **397,** (Publication not seen by compiler). Belongs to family Anomalinidae. Sub-Genotype:
—— *orcinus* Vassilenko, **397.** (Publication not available to compiler).
*Globigerina ciperoensis* Bolli, **43,** p. 1, text fig. 3,4. Oligocene, Trinidad. (For synonymy see original publication).
—— *hölzli* Hagn and Zeil, **172,** p. 50, pl. 2, fig. 8. Lower Turonian, Bavarian Alps, Germany.
—— *wilsoni* Cole, 1927, subsp. *bolivariana* Petters, **310,** p. 39, pl. 8, fig. 9. Middle Eocene, Colombia.
*Globigerinoides bispherica* Todd, **379,** p. 681, pl. 1, fig. 4. Upper Oligocene, Saipan. (For synonymy see original paper).
—— *subquadrata* Bronnimann in Todd, **379,** p. 680, pl. 1, fig. 5,8. Upper Oligocene, Trinidad and Saipan.
—— *triloba* (Reuss, 1850) var. *aspera* Petri, **309,** p. 125, pl. 12, fig. 12,13. Miocene, Brazil.
*Globobulimina mississippiensis* F. L. Parker, **305,** p. 511, pl. 7, fig. 3,4,10. Recent, Gulf of Mexico, 155 m.
*Globorotalia velascoensis* (Cushman, 1925) var. *parva* Rey, **335,** p. 209, pl. 12, fig. 1. Paleocene, Morocco. (Published January 1955).
*Globorotalia? youngi* Fox, **142,** p. 119, pl. 26, fig. 15–18. Cretaceous, S. Dakota and Wyoming.
*Globotruncana ansarii* Nakkady and Osman, **282,** p. 77, pl. 20, fig. 17. Upper Cretaceous, Egypt.
—— *pooleyi* Nakkady and Osman, **282,** p. 82, pl. 19, fig. 4. Upper Cretaceous, Egypt.
—— *pseudofornicata* Nakkady and Osman, **282,** p. 82, pl. 19, fig. 2. Upper Cretaceous, Egypt.
—— *qabeliatensis* Nakkady and Osman, **282,** p. 83, text fig. a,b,c. Upper Cretaceous, Egypt.
—— *quadrata* Nakkady and Osman, **282,** p. 83, pl. 20, fig. 18. Upper Cretaceous, Egypt.
—— —— —— var. *plata* Nakkady and Osman, **282,** p. 84, pl. 20, fig. 23. Upper Cretaceous, Egypt.
—— *sudrensis* Nakkady and Osman, **282,** p. 85, pl. 19, fig. 5. Upper Cretaceous, Egypt.
—— —— —— var. *parallela* Nakkady and Osman, **282,** p. 85, pl. 19, fig. 6. Upper Cretaceous, Egypt.
*Glomospira charoides* (Jones and Parker, 1860) var. *extendens* Emiliani, **126,** p. 133, pl. 23, fig. 14. Oligocene, Italy. (For synonymy consult original publication).
—— *favilla* Emiliani, **126,** p. 133, pl. 23, fig. 15. Oligocene, Italy. (For synonymy see original publication).
*Goësella mississippiensis* F. L. Parker, **305,** p. 495, pl. 3, fig. 13,14,19. Recent, Gulf of Mexico, 210 m.
*Gümbelina? marshallana* Todd, **94,** p. 349, pl. 87, fig. 9. Recent (or reworked?), Marshall Islands.
*Gümbelitria cretacea* Cushman, 1933, subsp. *albertensis* Stelck and Wall, **361,** p. 23, pl. 2, fig. 19. Upper Cretaceous, Western Canada.
*Guttulina asanoi* Iwasa and Kikuchi, **213,** p. 191, text fig. 4. Miocene, Japan.
—— *irregularis* (Orbigny, 1839) var. *contraria* Petri, **309,** p. 68, pl. 4, fig.3–5. Miocene, Brazil.
—— *rivadaviaensis* Camacho, **65,** p. 33, pl. 6, fig. 13. Upper Cretaceous, Argentina.
*Gyroidina barbarica* Emiliani, **126,** p. 135, pl. 24, fig. 2. Oligocene, Italy.
—— *gothica* Emiliani, **126,** p. 135, pl. 24, fig. 4. Oligocene, Italy. (For synonymy see original paper).
—— *medicea* Emiliani, **126,** p. 136, pl. 24, fig. 6. Oligocene, Italy.
—— *patagonica* Camacho, **65,** p. 34, pl. 6, fig. 21. Upper Cretaceous, Argentina.
*Halkyardia bikiniensis* Cole, **81,** p. 584, pl. 210, fig. 1–5. Oligocene, Bikini.
*Haplophragmella didona* Malakhova, **251,** p. 57, pl. 1, fig. 19,20. Tournaisian, western Urals, U.S.S.R.
*Haplophragmoides bonanzaense* Stelck and Wall, **361,** p. 24, pl. 2, fig. 10. Upper Cretaceous, Western Canada.

— *carlilensis* Fox, **142,** p. 110, pl. 24, fig. 2,3. Cretaceous, S. Dakota, Wyoming.
— *diversitatum* Stelck and Wall, **361,** p. 24, pl. 1, fig. 8,9; pl. 2, fig. 3. Upper Cretaceous, Western Canada.
— *etrusca* Emiliani, **126,** p. 139. Not figured. Oligocene, Italy.
— *hendersonense* Stelck and Wall, **361,** p. 25, pl. 2, fig. 4. Upper Cretaceous, Western Canada.
— *howardense* Stelck and Wall, **361,** p. 25, pl. 1, fig. 20; pl. 2, fig. 5,6. Upper Cretaceous, Western Canada.
— — — — subsp. *manifestum* Stelck and Wall, **361,** p. 26, pl. 1, fig. 3–5,18; pl. 2, fig. 1,2. Upper Cretaceous, Western Canada.
— *spiritense* Stelck and Wall, **361,** p. 28, pl. 2, fig. 7–9. Upper Cretaceous, Western Canada.
— *tremblayense* Stelck and Wall, **361,** p. 29, pl. 1, figs. 6, 7. Upper Cretaceous, Western Canada.
*Hastigerinella colombiana* Petters, **310,** p. 40, pl. 8, fig. 10. Middle Eocene, Colombia.
*Hauerina millettii* Cushman, **94,** p. 337, pl. 84, fig. 23. Recent, Marshall Islands. For: *Miliolina circularis* Bornemann var. *sublineata* Brady in Millett, 1898, Jour. R. Micr. Soc. London, p. 501, pl. 11, fig. 4.
— *serrata* Cushman, **94,** p. 337, pl. 84, fig. 26,27. Recent, Marshall Islands.
HENSONIA gen. nov. Marie, **256,** p. 121. New genus of the family Verneuilinidae. Genotype: *Hensonia tricarinata* Marie, 1954, *ut infra*. Upper Cretaceous (Senonian).
— *tricarinata* Marie, **256,** p. 121, text fig. 4. Senonian, France and Spain.
*Heterostegina complanata* (Defrance, 1822) subsp. *sculpturata* Papp and Küpper, **302,** pl. 121, text pl. 5, fig. 4,5; pl. 23, fig. 4. Upper Miocene, Egypt.
— — (— —) subsp. *spiralis* Papp and Küpper, **302,** p. 121, text pl. 5, fig. 3; pl. 23, fig. 1. Mio-Pliocene, Crete, Greece.
— *costata* Orbigny, 1846, subsp. *carinata* Papp and Küpper, **302,** p. 117, pl. 21, fig. 1. Tortonian, Czechoslovakia.
— — — subsp. *levitesta* Papp and Küpper, **302,** p. 116, text pl. 3, fig. 6,7; pl. 23, fig. 2. Tortonian, Austria.
— — — subsp. *politatesta* Papp and Küpper, **302,** p. 117, text pl. 3, fig. 13–15; pl. 21, fig. 2. Tortonian, Austria.
— *granulatesta* Papp and Küpper, 1952, subsp. *praeformis* Papp and Küpper, **302,** p. 122, pl. 22, fig. 6,7. Helvetian, France.
— *heterostegina* (Silvestri, 1907) subsp. *praecostata* Papp and Küpper, **302,** p. 116, text pl. 3, fig. 1–4; pl. 21, fig. 7,8. Tortonian, Austria.
— *involutiformis* Papp and Küpper, **302,** p.124, text pl. 5, fig. 6,7. Upper Burdigalian, France.
— *nigripustula* Cole, **81,** p. 575, pl. 209, fig. 1–8. Lower Miocene, Bikini.
— *pusillumbonata* Cole, **81,** p. 576, pl. 206, fig. 3–9. Lower Miocene, Bikini.
HILTERMANNIA gen. nov. Hofker, **191,** p. 169. New genus of the family Epistomariidae. Genotype: *Epistomina chapmani* Dam, 1948, Revue Inst. Franç. Pétrole, vol. 3, p. 166, pl. 1, fig. 5. Albian and Aptian.
*Höglundina hyalina* Hofker, **191,** p. 203, text fig. 53,54. Recent, Caribbean Sea, off Santa Cruz, 150–500 fathoms.
— *mediterranea* Hofker, **191,** p. 202, text fig. 51,52. Recent, Mediterranean Sea, depths 200–400 m. (For: *Epistomina elegans* auctorum).
— *minimalis* Hofker, **191,** p. 200, text fig. 46. Oligocene, Holland.
— *miocenica* Hofker, **191,** p. 200, text fig. 47,48. Miocene, Holland.
*Hyperammina baltica* Eisenack, **123,** p. 65, pl. 4, fig. 10,22. Silurian pebble, Baltic States.
— *kentuckyensis* Conkin, **89,** p. 166, pl. 31, fig. 1–6 lower half of plate. Mississippian, Kentucky, U.S.A.
— *moderata* Malakhova, **251,** p. 50, pl. 1, fig. 3. Tournaisian, western Urals, USSR.
— *pristis* Emiliani, **126,** p. 143, pl. 24, fig. 12. Oligocene, Italy.
*Karreriella marina* Proto Decima and Ferasin, **324,** p. 248, pl. 11, fig. 3. Eocene, Italy.
— *shangtaoensis* Chang, **71,** p. 61, pl. 1, fig. 7–10. Miocene, Taiwan.
— *termalis* Proto Decima and Ferasin, **324,** p. 249, pl. 11, fig. 4. Eocene, Italy.
KATHINA gen. nov. Smout, **355,** p. 61. New genus of the family Rotaliidae. Genotype: *Kathina delseota* Smout, 1954, *ut infra*. Paleocene.
— *delseota* Smout, **355,** p. 61, pl. 7, fig. 1–8. Paleocene, Qatar.
— *major* Smout, **355,** p. 63, pl. 6, fig. 1–10. Paleocene, Qatar.
— *selveri* Smout, **355,** p. 62, pl. 6, fig. 11–13. Paleocene, Qatar.
*Lagenonodosaria scalaris* (Batsch, 1791) var. *cuneensis* Martinis, **258,** p. 171, pl. 6, fig. 7. Pliocene, Italy.
*Lamellodiscorbis* see *Discorbis*
*Lenticulina ellisori* Bowen, **51,** p. 146, pl. A, fig. 13,14. Eocene, London Clay, England. (For: *Robulus propinquans* Hantken in Ellisor, 1933, Bull. Amer. Assoc. Petr. Geologists, vol. 17, p. 1320, pl. 7, fig. 12. (*Note*: correct spelling of species name is "*ellisorae*").
— *huziokai* Iwasa and Kikuchi, **213,** p. 191, text fig. 2. Miocene, Japan.
— *rivadaviaensis* Camacho, **65,** p. 32, pl. 5, fig. 1. Upper Cretaceous, Argentina.
— *vistulae* Bielecka and Pozaryski, **37,** p. 36, pl. 4, fig. 15. Upper Malm, Poland,
— — — var. *elongata* Bielecka and Pozaryski, **37,** p. 36, pl. 4, fig. 16. Upper Malm, Poland.
*Lepidocyclina* (*Nephrolepidina*) *augusticamerata* Cole, **81,** p. 585, pl. 217, fig. 1–5. Lower Miocene, Bikini.
— (— —) *bikiniensis* Cole, **81,** p. 586, pl. 214, fig. 1–8. Lower Miocene, Bikini.
— (— —) — — var. *unipilaris* Cole, **81,** p. 587, pl. 214, fig. 11–14,18. Lower Miocene, Bikini.
— (— —) *cubiculirhomboidea* Cole, **81,** p. 587, pl. 213, fig. 10–19. Miocene, Bikini.
— (— —) *pumilipapilla* Cole, **81,** p. 592, pl.

214, fig. 15–17,19; pl. 215, fig. 1–8. Lower Miocene, Bikini.

*Lepidocyclina* (*Eulepidina*) *abdopustula* Cole, **81,** p. 594, pl. 215, fig. 9,10; pl. 218, fig. 7–11. Oligocene, Bikini.

*Lepidolina? gigantea* Toriyama, **387,** p. 181, pl. 24. Permian, Japan.

*Lepidolina kumaensis* Kanmera, **217,** p. 22, pl. 5, fig. 1–13. Upper Permian, Japan.

—— *toriyamai* Kanmera, **217,** p. 24, pl. 6, fig. 1–19. Upper Permian, Japan.

*Lepidorbitoides minima* Douvillé, 1927, subsp. *pembergeri* Papp, **300,** p. 163, text fig. 3,4. Campanian, Austria.

*Liebusella exigua* Todd and Post, **380,** p. 554, pl. 198, fig. 5,6. Oligocene, Bikini.

*Lockhartia altispira* Smout, **355,** p. 51, pl. 4, fig. 4–6. Paleocene, Qatar.

—— *conica* Smout, **355,** p. 53, pl. 4, fig. 1–3. Paleocene, Qatar.

—— *diversa* Smout, **355,** p. 52, pl. 3, fig. 1–20. Paleocene, Qatar.

—— *hunti* Ovey, 1947, var. *pustulosa* Smout, **355,** p. 54, pl. 4, fig. 8–10. Lower Eocene, Qatar.

—— *prehaimei* Smout, **355,** p. 51, pl. 2, fig. 21,22; pl. 7, fig. 14. Basal Paleocene, Qatar.

*Marginulina buskensis* Bielecka and Pozaryski, **37,** p. 124, pl. 8, fig. 39. Upper Malm, Poland.

—— *delecta* Camacho, **65,** p. 33, pl. 6, fig. 12. Upper Cretaceous, Argentina.

—— *enbornensis* Bowen, **51,** p. 149, pl. B, fig. 1–4. Eocene, London Clay, England.

—— *idola* Frizzell, **143,** p. 158, pl. 9, fig. 26. Upper Cretaceous, Texas.

*Massilina placida* Todd and Post, **380,** p. 555, pl. 198, fig. 11,12. Oligocene, Bikini.

*Miliammina bisobscura* Stelck and Wall, **361,** p. 29, pl. 1, fig. 1. Upper Cretaceous, Western Canada.

MINOUXIA gen. nov. Marie, **256,** p. 119. New genus of the family Valvulinidae. Genotype: *Minouxia gumbelitrioides* Marie, 1954, *ut infra.* Upper Cretaceous.

—— *dordonica* Marie, **256,** p. 120, text fig. 3. Upper Cretaceous, France.

—— *gumbelitrioides* Marie, **256,** p. 120, text fig. 1. Upper Cretaceous, France.

*Miogypsina* (*Miogyspina*) *socini* Drooger, **107,** p. 233, pl. 2, fig. 20–24; text fig. 2. Miocene, Italy.

*Miogypsinoides grandipustula* Cole, **81,** p. 602, pl. 221, fig. 1–4,19–22; pl. 222, fig. 12. Lower Miocene, Bikini.

*Miscellanea miscella* (Archiac and Haime, 1854) var. *dukhani* Smout, **355,** p. 73, pl. 14, fig. 2–6. Topmost Paleocene, Qatar.

*Mississippina dehmi* Hagn, **169,** p. 19, pl. 3, fig. 14. Eocene, Bavaria, Germany.

*Navarella joaquini* Ciry and Rat, 1951, var. *helvetica* Maync, **267,** p. 141, pl. 27, fig. 7–10. Maestrichtian, Swiss Alps.

*Neobulimina varsoviensis* Bielecka and Pozaryski, **37,** p. 65, pl. 10, fig. 50. Upper Malm, Poland.

*Nephrolepidina* see *Lepidocyclina*

*Nodomorphina pulchra* Rey, **335,** p. 210, pl. 12, fig. 3. Eocene, Morocco (published January 1955).

*Nodosarella pliocenica* Soares de Carvalho and Colom, **356.** (Publication not seen by the compiler).

*Nodosaria subcanaliculata* (Neugeboren, 1856) var. *spinescens* Bowen, **51,** p. 155, pl. 5, fig. 9. Eocene, London Clay, England. (*Note:* Preoccupied by *Nodosaria spinescens* Reuss, 1865; see Homonyma 1954; changed to *Nodosaria neospinescens* Bowen, 1955.)

*Nonion dalpiazi* Ferasin, 133, (publication not seen by compiler). Miocene, Italy.

—— *pacificum* (Cushman, 1922) var. *lauensis* Kleinpell, **225,** p. 41, pl. 2, fig. 5,6. Neogene, Fiji.

—— *pauciloculum* Cushman, 1944, subsp. *albiumbilicatum* Weiss, **407,** p. 157, pl. 32, fig. 1,2. Pleistocene, New York, U.S.A.

—— *sorachiense* Asano, **20,** p. 48, text fig. 4,5. Upper Eocene, Hokkaido, Japan.

*Nonionella curvisulcata* Petri, **309,** p. 73, pl. 4, fig. 13–15. Miocene, Brazil.

—— *miocenica* Cushman, 1926, subsp. *gagarini* Boltovskoy, **45,** p. 169, pl. 9, fig. 4,5. Recent, Gulf of San Jorge, Argentina.

*Nubecularia mazoviensis* Bielecka and Pozaryski, **37,** p. 31, pl. 3, fig. 10. Upper Malm, Poland.

OINOMIKADOINA gen. nov. Matsunaga, **263,** p. 163. New genus of the family Anomalinidae, subfamily Cibicidinae. Genotype: *Oinomikadoina ogiensis* Matsunaga, 1954, *ut infra.* Upper Pliocene, Lower Pleistocene.

—— *ogiensis* Matsunaga, **263,** p. 163, text fig. 1–3. Upper Pliocene, Japan.

*Oketaella campensis* Thompson, **373,** p. 36, pl. 6, fig. 14,18,25–33. Wolfcampian, Texas.

—— *cheneyi* Thompson, **373,** p. 37, pl. 6, fig. 12,13,15–17. Wolfcampian, Texas.

—— *waldripenses* Thompson, **373,** p. 35, pl. 6, fig. 19–24. Wolfcampian, Texas.

*Operculina lucidisutura* Cole, **81,** p. 575, pl. 204, fig. 1–6. Upper Miocene, Bikini.

*Operculinella(?) oneataensis* Kleinpell, **225,** p. 50, pl. 4, fig. 5–8. Neogene, Fiji.

*Operculinoides amplicuneata* Cole, **81,** p. 573, pl. 204, fig. 7–10; 16–18. Upper Miocene, Bikini.

—— *bikiniensis* Cole, **81,** p. 574, pl. 204, fig. 19–23. Miocene, Bikini.

—— *rectilata* Cole, **81,** p. 575, pl. 204, fig. 11–15; pl. 205, fig. 15–17. Upper Miocene, Bikini.

*Ordovicina monostoma* Eisenack, **123,** p. 54, pl. 3, fig. 1. Silurian, Estland.

*Ozawainella? inflata* Thompson, **373,** p. 31, pl. 5, fig. 1–9. Wolfcampian, Texas and Arizona.

PARABOULTONIA gen. nov. Skinner and Wilde, **351,** p. 441. New genus of the family Fusulinidae, subfamily Boultoniinae. Genotype: *Paraboultonia splendens* Skinner and Wilde, 1954, *ut infra.* Permian.

—— *splendens* Skinner and Wilde, **351,** p. 441, pl. 46, fig. 1–7; pl. 45, fig. 1–4. Permian, Texas.

*Peneroplis honestus* Todd and Post, **380,** p. 557, pl. 199, fig. 1. Miocene, Bikini.

PHYLLOPSAMMINA gen. nov. Malecki, **253,** p. 503. New genus of the family Lituolidae, subfamily Lituolinae. Genotype: *Phyllopsammina adanula* Malecki, 1954, *ut infra.* Miocene.

—— *adanula* Malecki, **253,** p. 512, pl. 13, fig. 7–10. Miocene, Poland.

*Planularia chubutensis* Camacho, **65,** p. 32, pl. 6, fig. 9. Upper Cretaceous, Argentina.
— *wichmanni* Camacho, **65,** p. 32, pl. 5, fig. 2,3. Upper Cretaceous, Argentina.
*Planulina anglica* Bowen, **51,** p. 133, pl. A, fig. 1-3. Eocene, London Clay, England.
— *curviformis* Camacho, **65,** p. 32, pl. 6, fig. 17. Upper Cretaceous, Argentina.
— *dakotensis* Fox, **142,** p. 119, pl. 26, fig. 19–21. Cretaceous S. Dakota, Wyoming.
*Plectofrondicularia gracilis* Rey, **335,** p. 210, pl. 12, fig. 4. Eocene, Moracco. (Published January 1955).
*Pleurostomella subglobosa* Rey, **335,** p. 211, pl. 12, fig. 6. Oligocene, Morocco. (Published January 1955).
*Polyphragma codyensis* Fox, **142,** p. 113, pl. 25, fig. 1–4. Cretaceous S. Dakota and Wyoming. For: *Clavulina ?* sp. Wickenden, 1932, Journ. Paleont., vol. 6, p. 205, pl. 29, fig. 5; and for: *Polyphragma sp.* Cushman, 1946, U.S. Geol. Surv. Prof. Pap. 206, p. 15, pl. 15, fig. 15,16. (*Note:* This species should be assigned to *Coscinophragma* Thalmann, 1951).
PROCEROLAGENA gen. nov. Puri, **326,** p. 104. New genus of the family Lagenidae. Genotype: *Lagena gracilis* Williamson, 1848, Ann. Mag. Nat. Hist., (2) vol. 1, p. 13, pl. 1, fig. 5. Miocene to Recent.
*Profusulinella plummeri* Skinner and Wilde, **351,** p. 796, pl. 95, fig. 1–6. Early Pennsylvanian, Texas. (Published January 1955).
*Proteonina arrasensis* Stelck and Wall, **361,** p. 30, pl. 1, fig. 10,11. Upper Cretaceous, Western Canada.
— *? eurekaensis* Stelck and Wall, **361,** p. 30, pl. 1, fig. 16. Upper Cretaceous Western Canada.
*Psammosphaera rugosa* Eisenack, **123,** p. 58, pl. 3, fig. 8–10. Silurian, Estland.
*Pseudoclavulina euganea* Proto Decima and Ferasin, **324,** p. 247, pl. 11, fig. 2. Upper Eocene, Italy.
*Pseudodoliolina pseudolepida* (Deprat, 1912) subsp. *gravitesta* Kanmera, **217,** p. 12, pl. 2, fig. 1–6. Upper Permian, Japan. For: *Doliolina lepida* Gubler, 1935, Mém. Soc. géol. France, n.s., vol. 11, fasc. 4, p. 95, pl. 4, fig. 4–7; pl. 5, fig. 14,15.
*Pseudofusulina loringi* Thompson, **373,** p. 69, pl. 41, fig. 1–10. Wolfcampian, Arizona.
— *nelsoni* (Dunbar and Skinner, 1937) subsp. *opima* Thompson, **373,** p. 70, pl. 44, fig. 5,7–11. Wolfcampian, Texas. (For synonymy see original paper).
*Pseudofusulina ? moranensis* Thompson, **373,** p. 69, pl. 39, fig. 1–7; pl. 40, fig. 1–9. Wolfcampian, Texas and Kansas.
— *utahensis* Thompson and Bissell, **373,** p. 34, pl. 7, fig. 1–10. Wolfcampian, Utah.
*Pseudoglandulina tumida* Bowen, **51,** p. 157, pl. B, fig. 10. Eocene, London Clay, England.
PSEUDOLITUONELLA gen. nov. Marie, **256,** p. 117. New genus of the family Valvulinidae. Genotype: *Pseudolituonella reicheli* Marie, 1954, *ut infra*. Upper Cretaceous.
— *reicheli* Marie, **256,** p. 117, text fig. 2. Cenomanian, Southern France.
*Pseudoschwagerina convexa* Thompson, **373,** p. 75, pl. 44, fig. 1–4; pl. 51, fig. 1–8. Wolfcampian, Texas.
—— *needhami* Thompson, **373,** p. 72, pl. 47, fig. 7,8,11–17. Wolfcampian, New Mexico.
—— *rhodesi* Thompson, **373,** p. 73, pl. 50, fig. 1,2; pl. 51, fig. 9–11; pl. 52, fig. 1–6. Wolfcampian, New Mexico.
PSEUDOTRIPLASIA gen. nov. Malecki, **253,** p. 499. New genus of the family Lituolidae, subfamily Lituolinae. Genotype: *Pseudotriplasia elongata* Malecki, 1954, *ut infra*. Miocene.
—— *elongata* Malecki, **253,** p. 511, pl. 12, fig. 3,4. Miocene, Poland.
—— *globulosa* Malecki, **253,** p. 511, pl. 13, fig. 5. Miocene, Poland.
—— *inconstans* Malceki, **253,** p. 511, pl. 12, fig. 2. Miocene, Poland.
—— *plana* Malecki, **253,** p. 510, pl. 12, fig. 1. Miocene, Poland.
—— *robusta* Malecki, **253,** p. 510, pl. 13, fig. 6. Miocene, Poland.
*Pullenia quinqueloba* Reuss, 1851 subsp. *minuta* Feyling-Hanssen, **135,** p. 133, pl. 2, fig. 3. Late Pleistocene, Norway. (*Note:* Preoccupied by *Pullenia minuta* Cushman, 1936, see Homonyma 1954. To be changed to *Pullenia osloensis* nom. nov. Hansen, according to letter dated March 15, 1954).
*Quinqueloculina urbana* Malakhova, **251,**, p. 59, pl. 1, fig. 11,12. Tournaisian, western Urals, USSR.
—— *distorqueata* Cushman, **94,** p. 333, pl. 82, fig. 27. Recent, Marshall Islands.
—— *pentagona* Giunta, **152,** p. 35, text fig. 2. Recent, Gulf of Genova, 75 and 125 m.
*Ramulina bullardae* Frizzell, **143,** p. 149. Upper Cretaceous, Texas. For: *Ramulina novaculeata* Bullard, 1953, (in part), Jour. Paleont., vol. 27, p. 346, pl. 46, fig. 26 (exclusive of Bullard's synonymy).
REICHELINA gen. nov. Marie, **256,** p. 122. New genus of the family Vernuilinidae. Genotype: *Reichelina prismatica* Marie, 1954, *ut infra*. Upper Cretaceous (Senonian). (*Note:* Preoccupied by *Reichelina*, Erk, 1941, see Homonyma 1954).
—— *prismatica* Marie, **256,** p. 123, text fig. 5. Senonian, France.
*Reophax encantoensis* Ayala, Eternod and Castelló, **27,** p. 153. text fig. 1–3. Lower Miocene, Southeastern Mexico.
—— *irregularis* F. L. Parker, **305,** p. 483, pl. 1, fig. 9,10. Recent, Gulf of Mexico, 91 m.
—— *romanica* Emiliani, **126,** p. 156, pl. 25, fig. 9. Oligocene, Italy.
*Reussella szajnochae* (Grzybowski, 1896) subsp. *praecursor* Klasz and Knipscheer, **223,** p. 603, table fig. 1a–c. Santonian, Bavarian Alps.
—— *tricarinata* Nyirö, **295,** (publication not seen by compiler), illustr. Chattian, Hungary.
*Rhabdammina vaciva* Emiliani, **126,** p. 158, pl. 25, fig. 11. Oligocene, Italy. For: *Rhabdammina discreta* var., Cushman and Renz, 1946, Cushman Lab. Foram. Res., Spec. Publ. 18, p. 12, pl. 1, fig. 2,3.
*Robertina conatoi* Martinis, **258,** p. 172, pl. 6, fig. 12,13. Pliocene, Italy.

*Robulus bullatus* (Hantken, 1875) var. *carinatus* Proto Decima and Ferasin, **324,** p. 249, pl. 11, fig. 5. Upper Eocene, Italy. (*Note:* preoccupied by Plummer, 1926, and by Marks, 1951, see Homonyma 1954).

—— *limbosus* (Reuss, 1863) subsp. *chiriguanoi* Boltovskoy, **45,** p. 143, pl. 5, fig. 1–5. Recent, Gulf of San Jorge, Argentina.

—— cf. *smileyi* Kleinpell, 1938, var. *pauciloculata* Petri, **309,** p. 59, pl. 3, fig. 3,4. Miocene, Brazil.

—— *sugotaensis* Iwasa and Kikichu, **213,** p. 191, text fig. 1. Miocene, Japan.

*Rotalia canalis* Todd and Post, **380,** p. 561, pl. 200, fig. 4. Upper Miocene, Bikini.

—— *dukhani* Smout, **355,** p. 46, pl. 15, fig. 7. Paleocene, Qatar.

—— *floscula* Todd and Post, **380,** p. 561, pl. 200, fig. 5. Oligocene, Bikini.

—— *hensoni* Smout, **355,** p. 45, pl. 15, fig. 8. Paleocene, Qatar.

—— *tanosawaensis* Iwasa and Kikuchi, **213,** p. 192, text fig. 7. Miocene, Japan.

—— *tectoria* Todd and Post, **380,** p. 561, pl. 202, fig. 2–4. Oligocene, Bikini.

—— *tuvuthaensis* Kleinpell, **225,** p. 61, pl. 7, fig. 1–4. Neogene, Fiji.

"*Rotalia*" *beccarii* (Linne, 1758) var. *angulata* Petri, **309,** p. 106, pl. 9, fig. 10–12. Miocene, Brazil. (*Note:* preoccupied by Kuwano, 1950, see Homonyma 1954; re-named *Streblus beccarii* (Linne) var. *mendesi* Petri, 1955.)

ROTALIELLA gen. nov. Grell, **159,** p. 241. Family not stated. Genotype: *Rotaliella heterocaryotica* Grell, 1954, *ut infra.* Recent.

—— *heterocaryotica* Grell, **159,** p. 241, text fig. 1a,b. Recent, off Rovinjo, Yugoslavia.

*Rotalipora turonica* Brotzen, 1942, subsp. *thomei* Hagn and Zeil, **172,** p. 28, pl. 1, fig. 6; pl. 4, fig. 5,6. Upper Cenomanian, Bavarian Alps.

*Rugidia ? spinosa* Cushman, **94,** p. 362, pl. 89, fig. 35–37. Recent, Marshall Islands.

*Sakesaria dukhani* Smout, **355,** p. 57, pl. 5, figs. 4–12. Paleocene, Qatar.

—— —— —— var. *cordata* Smout, **355,** p. 58, pl. 5, fig. 13. Paleocene, Qatar.

—— *ornata* Smout, **355,** p. 58, pl. 5, figs. 14,15. Upper Paleocene, Qatar.

*Saracenaria akitaensis* Iwasa and Kikichu, **213,** p. 191, text fig. 3. Miocene, Japan.

—— *reesidei* Fox, **142,** p. 114, pl. 25, fig. 7–9. Cretaceous, S. Dakota and Wyoming.

SCHLOSSERINA gen. nov. Hagn, **169,** p. 18. New genus of the family Rotaliidae, subfamily Epistomininae. Genotype: *Rosalina asterites* Gümbel, 1868, Abhandl. math.-phys. Cl., K. Bayer, Akad. Wiss., vol. 10, 1868 (1870), p. 658, pl. 2, fig. 101. Eocene.

*Schwagerina andresensis* Thompson, **373,** p. 60, pl. 31, fig. 1–16. Wolfcampian, New Mexico.

—— *campa* Thompson, **373,** p. 54, pl. 25, fig. 1–10. Wolfcampian, Kansas.

—— *campensis* Thompson, **373,** p. 57, pl. 26, fig. 10; pl. 28, fig. 1–15. Wolfcampian, Texas.

——*colemani* Thompson, **373,**, p. 51, pl. 24, fig. 6–15. Wolfcampian, Texas.

—— *complexa* Thompson, **373,** p. 65, pl. 38, fig. 1–7; pl. 39, fig. 8,9. Wolfcampian, Texas and Kansas.

—— *elkoensis* Thompson and Hansen, **373,** p. 63, pl. 35, fig. 1–9, ?14–20. Wolfcampian, Nevada.

—— *eolata* Thompson, **373,** p. 64, pl. 36, fig. 1–8. Wolfcampian, Texas.

—— *grandensis* Thompson, **373,** p. 59, pl. 24, fig. 1–5; 16–24; pl. 29, fig. 15, 16; pl. 32, fig. 10–18; pl. 33, ?fig. 15. Wolfcampian, New Mexico.

—— *jewetti* Thompson, **373,** p. 61, pl. 25, fig. 11–13; pl. 30, fig. 1–9. Wolfcampian, Kansas.

—— *minuta* Thompson, **373,** p. 53, pl. 43, fig. 1–10. Wolfcampian, Texas

—— *neolata* Thompson, **373,** p. 65, pl. 36, fig. 9–15. Wolfcampian, Texas.

—— *pinosensis* Thompson, **373,** p. 58, pl. 33, fig. 1–12, ?13–14. Wolfcampian, New Mexico.

—— *pseudocrassa* Kanmera, **217,** p. 8, pl. 1, fig. 8–17; pl. 3, fig. 21. Upper Permian, Japan. (For synonymy see original paper).

—— *robleda* Thompson, **373,** p. 68, pl. 42, fig. 4–11. Wolfcampian, New Mexico and Utah.

—— *vervillei* Thompson, **373,** p. 62, pl. 29, fig. 1–14. Wolfcampian, Kansas.

—— *wellsensis* Thompson and Hansen, **373,** p. 64, pl. 32, fig. 1–6 ?7–9; pl. 34, fig. 1–12. Wolfcampian, Nevada.

—— *youngquisti* Thompson and Hansen, **373,** p. 67, pl. 37, fig. 6–11. Wolfcampian, Nevada.

*Siderolites mbalavuensis* Kleinpell, **225,** p. 67, pl. 7, fig. 9. Neogene, Fiji.

*Sigmomorphina inovroclaviensis* Bielecka and Pozaryski, **37,** p. 63, pl. 9, fig. 47. Upper Malm, Poland.

—— *translucida* Camacho, **65,** p. 33, pl. 6, fig. 8. Upper Cretaceous, Argentina.

*Siphogenerinoides uhli* Petters, **310,** p. 38, pl. 8, fig. 4,5. Campanian, Colombia.

*Sorosphaera geometrica* Eisenack, **123,** p. 61, pl. 4, fig. 19,20; pl. 5, fig. 2–6; text fig. 1. Silurian, Gotland Island.

*Spirillina elongata* Bielecka and Pozaryski, **37,** p. 67, pl. 10, fig. 53. Upper Malm, Poland.

*Spiroloculina clara* Cushman, 1932, var. *lirata* Cushman, **94,** p. 335, pl. 84, fig. 10. Recent, Marshall Islands.

—— *concava* Petri, **309,** p. 53, pl. 2, fig. 3–6. Miocene, Brazil. (*Note:* Preoccupied by Wiesner, 1913, see Homonyma 1954; renamed *Spiroloculina henbesti* Petri 1955).

—— *marshallana* Todd, **94,** p. 335, pl. 84, fig. 8. Recent, Marshall Islands.

*Spiroplectammina apenninica* Emiliani, **126,** p. 162, pl. 25, fig. 14–15. Oligocene, Italy.

—— *guttula* Malakhova, **251,** p. 59, pl. 1, fig. 17,18. Tournaisian, western Urals, USSR.

—— *zigzag* Petters, **310,** p. 38, fig. 2,3. Lower Oligocene, Colombia.

*Stegnammina moremani* Eisenack, **123,** p. 63, pl. 2, fig. 13; pl. 3, fig. 2; pl. 5, fig. 7–10. Silurian, Gotland Island.

*Stensiöina annae* Pozaryska, **323,** p. 265, text fig. 24,25, Danian, Poland.

STETSONIA gen. nov. F. L. Parker, **305,** p. 534. New genus of the family Cassidulinidae. Geno-

type: *Stetsonia minuta* F. L. Parker, 1943, *ut infra*. Recent.
—— *minuta* F. L. Parker, **305,** p. 534, pl. 10, fig. 27–29. Recent, Gulf of Mexico, 42 m.
SULCORBITOIDES gen. nov. Bronnimann, **54,** p. 55. New genus of the family Orbitoididae. Genotype: *Sulcorbitoides pardoi* Bronnimann, 1954, *ut infra*. Upper Cretaceous.
—— *pardoi* Bronnimann, **54,** p. 56, pl. 9, fig. 1–4; pl. 10, fig. 1–9; pl. 11, fig. 1–10. Upper Cretaceous, Cuba and Texas.
*Textularia curta* Petri, **309,** p. 46, pl. 1, fig. 1,2. Miocene, Brazil. (*Note:* Preoccupied by Cushman, 1922, see Homonyma 1954; re-named *Textularia leinzi* Petri, 1955).
—— *dupla* Todd, **94,** p. 329, pl. 83, fig. 6. Recent, Marshall Islands.
—— *marajoara* Petri, **309,** p. 47, pl. 1, fig. 3,4. Miocene, Brazil.
—— *oveyi* Bowen, **51,** p. 166, pl. D, fig. 2,3. Eocene, London Clay, England.
—— *rollaensis* Stelck and Wall, **361,** p. 30, pl. 1, fig. 17. Upper Cretaceous, Western Canada.
*Thurammina asymmetrica* Eisenack, **123,** p. 64, pl. 4, fig. 4–6. Silurian pebble, Baltic States.
TINOGULLMIA gen. nov. Nyholm, **294,** p. 36. New genus of the family Allogromiidae. Genotype: *Tinogullmia hyalina* Nyholm, 1954, *ut infra*. Recent.
—— *hyalina* Nyholm, **294,** p. 36, pl. 7, fig. 1–8. Recent, Gullmar Fiord, Sweden.
*Tournayella modesta* Malakhova, **251,** p. 55, pl. 2, fig. 6. Tournaisian, western Urals.
—— *questita* Malakhova, **251,** p. 54, pl. 2, fig. 3,5. Tournaisian, western Urals.
—— *? moelleri* Malakhova, **251,** p. 55, pl. 2, fig. 2,4. Tournaisian, western Urals.
TRIASINA gen. nov. Majzon, **250,** p. 368. New genus of the family Peneroplidae. Genotype: *Triasina hantkeni* Majzon, 1954, *ut infra*. (Publication not seen by compiler). Triassic.
—— *hantkeni* Majzon, **250,** (publication not seen by compiler), illustr. Triassic, Hungary.
—— —— —— var. *elliptica* Majzon, **250,** (Publication not seen by compiler). Triassic, Hungary.
*Triloculina bikiniensis* Todd, **94,** p. 338, pl. 85, fig. 19. Recent, Marshall Islands.
—— *earlandi* Todd, **94,** p. 338, pl. 85, fig. 3. Recent, Marshall Islands. For: *Miliolina terquemiana* Brady in Heron-Allen and Earland, 1915, Zool. Soc. London, Trans., vol. 20, p. 563, pl. 41, figs. 26–28 (*non* figs. 29–31).
—— *fusa* Todd and Post, **380,** p. 555, pl. 198, fig. 8. Lower Miocene, Bikini.
—— *involuta* Todd, **94,** p. 338, pl. 85, fig. 4. Recent, Marshall Islands.
—— *marshallana* Todd, **94,** p. 339, pl. 85, fig. 13. Recent, Marshall Islands.
—— *subplanciana* Cushman, **94,** p. 339, pl. 85, fig. 17. Recent, Marshall Islands.
*Tritaxia spiritensis* Stelck and Wall, **361,** p. 31, pl. 2, fig. 12–14. Upper Cretaceous, Western Canada.
—— —— —— var. *elongata* Stelck and Wall, **361,** p. 32, pl. 2, fig. 15. Upper Cretaceous, Western Canada. (*Note:* Preoccupied by Halkyard, 1919, see Homonyma 1954; renamed *Tritaxia spiritensis* var. *prolongata* Stelck and Wall, 1955.)
*Triticites cellamagnus* Thompson and Bissell, **373,** p. 43, pl. 10, fig. 14–17; pl. 11, fig. 1–12. Wolfcampian, Utah.
—— *confertus* Thompson, **373,** p. 38, pl. 8, fig. 11–22. Wolfcampian, Texas and Kansas.
—— *creekensis* Thompson, **373,** p. 42, pl. 9, fig. 22–26; pl. 10, fig. 1–13. Wolfcampian, New Mexico.
—— *directus* Thompson, **373,** p. 38, pl. 8, fig. 1–10, ? 23–26. Wolfcampian, Texas.
—— *pointensis* Thompson, **373,** p. 37, pl. 9, fig. 1–9. Wolfcampian, Kansas.
—— *rockensis* Thompson, **373,** p. 44, pl. 9, fig. 10–21. Wolfcampian, Kansas.
*Trochammina kiskatinawensis* Stelck and Wall, **361,** p. 32, pl. 1, fig. 12,13. Upper Cretaceous, western Canada. (*Note:* misspelled "*kistatinawensis*").
—— *latumbilicata* Stelck and Wall, **361,** p. 33, pl. 1, fig. 14,15. Upper Cretaceous, western Canada.
—— *webbi* Stelck and Wall, **361,** p. 33, pl. 2, fig. 11. Upper Cretaceous, western Canada.
*Trocholina solecensis* Bielecka and Pozaryski, **37,** p. 69, pl. 11, fig. 57. Upper Malm, Poland.
*Uvigerina canariensis* Orbigny, 1839, var. *lakembaensis* Kleinpell, **225,** p. 54, pl. 2, fig. 13. Neogene, Fiji.
*Vaginulina chugokuensis* Murata, **278,** p. 73, pl. 1, fig. 3. Miocene, Japan.
—— *kujaviensis* Bielecka and Pozaryski, **37,** p. 46, pl. 6, fig. 28. Upper Malm, Poland.
—— *zaglobensis* Bielecka and Pozaryski, **37,** p. 42, pl. 6, fig. 23. Upper Malm, Poland.
—— —— —— var. *parallela* Bielecka and Pozaryski, **37,** p. 45, pl. 6, fig. 27. Upper Malm, Poland. (*Note:* Preoccupied by Halkyard, 1919, see Homonyma 1954).
*Valvulammina marshallana* Todd and Post, **380,** p. 554, pl. 198, fig. 3. Miocene, Bikini.
*Valvulina ? prominens* Todd and Post, **380,** p. 553, pl. 198, fig. 2. Miocene, Bikini.
*Valvulineria barnardi* Bowen, **51,** p. 165, pl. C, fig. 16–18. Eocene, London Clay, England.
—— *mexicana* F. L. Parker, **305,** p. 526, pl. 9, fig. 1–3. Recent, Gulf of Mexico, 373 m. For: *Valvulineria* cf. *araucana* (Orbigny) in Phleger and Parker, 1951, Mem. Geol. Soc. America, vol. 46, pt. 2, p. 25, pl. 13, fig. 7,8.
—— *minuta* F. L. Parker, **305,** p. 527, pl. 9, fig. 4–6. Recent, Gulf of Mexico, 274 m.
*Vaughanina barkeri* Bronnimann, **56,** p. 103, pl. 18, fig. 1,2.; text fig. 10. Upper Cretaceous, Southeast Mexico. For: *Vaughanina cubensis* Palmer in Barker and Grimsdale, 1937, Ann. Mag. Nat. Hist., (10), vol. 19, p. 173.
*Virgulina loeblichi* Feyling-Hanssen, **136,** p. 191, pl. 1, fig. 14–18, text fig. 3. Late Pleistocene, Norway. (for synonymy see original publication).
—— *riggi* Boltovskoy, **45,** p. 186, pl. 11, fig. 15; pl. 12, fig. 7–11. Recent, Gulf of San Jorge, Argentina.

*Vitriwebbina biosculata* Frizzell, **143,** p. 158, pl. 15, fig. 7. Upper Cretaceous, Texas.

VOORTHUYSENIA gen. nov. Hofker, **191,** p. 169. New genus of the family Epistomariidae. Genotype: *Epistomina tenuicostata* Bartenstein, 1951, Abhandl. Senckenberg. Naturforsch. Ges., vol. 485, p. 327, pl. 12-a, fig. 325. Middle Jurassic to Lower Cretaceous.

—— *brandi* Hofker, **191,** p. 183, text fig. 13–16. Dogger, Germany.

—— *pachyderma* Hofker, **191,** p. 185, text fig. 17. Dogger, Germany.

—— *parafavosoides* Hofker, **191,** p. 186, text fig. 18. Lower Cretaceous, Germany.

WHEELERELLA gen. nov. Petters, **310,** p. 38. New genus of the family Ellipsoidinidae, subfamily Wheelerellinae Petters, 1954, *ut infra*. Genotype: *Wheelerella magdalenaensis* Petters, 1954, *ut infra*. Upper Cretaceous.

—— *magdalenaensis* Petters, **310,** p. 39, pl. 8, fig. 6–8. Coniacian, Colombia.

WHEELERELLINAE subfam. nov. Petters, **310,** p. 39. Includes the genera: *Wheelerella* Petters, 1954, *ut supra*, and possibly also *Ellipsolingulina* Silvestri, 1907.

*Yabeina gubleri* Kanmera, **217,** p. 19, pl. 4, fig. 1–10, ? 11, 12–13. Upper Permian, Japan.

### NOMINA NOVA 1954

*Bolivina usensis* nom. nov. Conato, **88,** p. 38. New name for *Bolivina ornata* Conato, 1953, Boll. Serv. Geol. Italia, vol. 74, p. 161, pl. 1 (non *Bolivina advena* Cushman var. *ornata* Cushman, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, p. 29, pl. 5, fig. 2). Pliocene, Italy.

*Bulimina subtruncana* nom. nov. Hagn, **169,** p. 17. Eocene Bavaria. New name for *Bulimina truncana* (Gümbel) in Cushman and F. L. Parker, 1947, U. S. Geol. Surv. Prof. Pap. 210-D, pl. 21, fig. 7,8.

*Cibicides mexicanus* (Nuttall, 1932) var. *dertonensis* nom. nov. Ruscelli, **345,** p. 256. New name for *Cibicides mexicanus* (Nuttall, 1932) var. *miocenicus* Ruscelli, 1953, Riv. Ital. Paleont. e Strat., Mem. VI, p. 158, pl. 7, fig. 1–3, (non *Cibicides floridanus* (Cushman, 1918) var. *miocenicus* Colom, 1945, Estud. Geol. No. 3, Inst. "Lucas Mallada" Madrid, p. 173, pl. 12, fig. 248, etc.).

*Dorothia fallax* nom. nov. Hagn, **169,** p. 16. Eocene, Bavaria. New name for *Dorothia subglabra* (Gümbel) in Cushman, 1937, Cushman Lab. Foram. Res., Spec. Publ., 8, p. 86, pl. 9, fig. 13,14.

*Fissurina siciliensis* nom. nov. Loeblich and Tappan, **246,** p. 384. New name for *Fissurina marginata* Seguenza, 1862, Foram. Monotalam. Mioc. Messina, p. 66, pl. 2, fig. 27,28 (non *Vermiculum marginatum* Montagu, 1803, Testac. Britannica, p. 524).

*Nodosaria cornus* nom. nov. Emiliani, **126,** p. 147. Oligocene, Italy. New name for *Nodosaria corniculum* Costa, 1856, Accad. Pont. Napoli, Atti, vol. 7, p. 370, pl. 27, fig. 14 [non *Dentalina* (*Nodosaria*) *cornicula* Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 255, No. 47.]

*Nonion paralium* nom. nov. Tintant, **375,** p. 188, pl. 2, fig. 1. Astian, Turkey, Recent, Atlantic and Mediterranean Sea. New name for: *Nonionina depressula* (Walker and Jacob) in Brady, 1884, Challenger Repts., Zool. vol. 9, p. 730, pl. 109, fig. 6.

*Oolina borealis* nom. nov. Loeblich and Tappan, **246,** p. 384. New name for *Entosolenia costata* Williamson, 1858, Rec. Foram. Great Britain, p. 9, pl. 1, fig. 18 (non *Oolina costata* Egger, 1857, N. Jahrb. Min. etc., p. 269, pl. 5, figs. 9–11).

PIJPERSIA nom. nov. Thalmann, **369,** p. 153. New name for *Ruttenia* Pijpers, 1933, non *Ruttenia* Rodhain, 1924. Genotype: *Bonairea coronaeformis* Pijpers, 1933. Eocene.

*Quinqueloculina norvangi* nom. nov. Boltovskoy, **45,** p. 126, pl. 1, fig. 13. Recent, Gulf of San Jorge, Argentina. New name for *Quinqueloculina nitida* Norvang, 1945, Zool. Iceland, vol. 2, pt. 2, p. 7, text fig. 1. [non *Triloculina* (*Quinqueloculina*) *nitida* Orbigny, 1839, in Barker, Webb and Berthelot, Hist. Nat. Iles Canaries, vol. 2, pt. 2, Foram., p. 141, pl. 3, fig. 22–24.]

*Spiroloculina bornemanni* nom. nov. Emiliani, **126,** p. 161. Oligocene, Italy. New name for: *Spiroloculina limbata* Bornemann, 1855, Zeitschr. Deutsche Geol. Ges., vol. 7, p. 348, pl. 19, fig. 1 (non *Spirolocuiina limbata* Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 299, No. 12). (*Note:* Bornemann's species has been regarded by Cushman, 1944, Spec. Publ. 11, Cushman Lab. Foram. Res., p. 22, as a synonym of *Spiroloculina canaliculata* Orbigny, 1846).

—— *concava* nom. nov. Petri, **309,** p. 53, pl. 2, fig. 3–6. Miocene, Brazil. New name for *Spiroloculina planulata* (Lamarck) in Cushman, 1929, U.S. Nat. Mus., Bull. 104, pt. 6, p. 41, pl. 8, fig. 2–5. (*Note:* Petri's new name is preoccupied by Wiesner, 1913, see Homonyma 1954. It has since been renamed: *Spiroloculina henbesti* nom. nov. Petri, 1955.)

### HOMONYMA 1954

*Bolivina lanceolata* F. L. Parker, **305,** p. 514, pl. 7, fig. 17–20, Recent, Gulf of Mexico, preoccupied by *Bolivina lanceolata* Napoli Alliata, 1952, Riv. Ital. Paleont. e Strat., vol. 58, p. 98, pl. 5, fig. 10, Pleistocene, Italy. Changed to *Bolivina daggarius* F. L. Parker, 1955.

*Elphidium ? limbatus* Petri, **309,** p. 75, fig. 1,2. Miocene, Brazil; preoccupied by *Elphidium macellum* (Fichtel and Moll) var. *limbatum* (Chapman, 1907), Jour. Queckett Micr. Club., (2), vol. 10, p. 142, pl. 10, fig. 9. Renamed *Elphidium ? toddae* Petri, 1955.

*Nodosaria subcanaliculata* (Neugeboren) var. *spinescens* Bowen, **51,** p. 155, pl. B, fig. 9, Eocene, London Clay, England, preoccupied by *Nodosaria* (*Dentalina*) *spinescens* Reuss, 1865, Denkschr. k. k. Akad. Wiss. Wien, vol. 25, p. 135, pl. 2, fig. 23 from Middle Oligocene of Germany. Renamed: *Nodosaria neospinescens* Bowen, 1955.

*Pullenia quinqueloba* Reuss, 1851, subsp. *minuta*, Feyling-Hanssen, **135,** p. 133, pl. 2, fig. 3, Late Pleistocene of Norway, preoccupied by *Pul-*

*lenia minuta* Cushman, 1936, Contr. Cushman Lab. Foram. Res., vol. 12, p. 77, pl. 13, fig. 7 from Upper Cretaceous of Texas. Will be changed to *Pullenia osloensis* Feyling-Hanssen, according to letter dated March 15, 1954.

REICHELINA Marie, **256,** p. 122, from the Upper Cretaceous is preoccupied by *Reichelina* Erk, 1941, Eclogae Geol. Helvetiae, vol. 34, p. 249, a fusuline genus.

*Robulus bullatus* (Hantken) var. *carinatus* Proto Decima and Ferasin, **324,** p. 249, pl. 11, fig. 5, Eocene, Italy, is preoccupied by a) *Robulus midwayensis* (Plummer) var. *carinatus* Plummer, 1926, and b) *Robulus clericii* (Fornasini, 1901) var. *carinatus* Marks, 1951.

*"Rotalia" beccarii* (Linne) var. *angulata* Petri, **309,** p. 106, pl. 9, fig. 10–12, Miocene, Brazil, is preoccupied by *Rotalia ketienziensis* (Ishizaki, 1943) var. *angulata* Kuwano, 1950, Jour. Geol. Soc. Japan, vol. 46, p. 312, text fig. 1,9. Changed to *Streblus beccarii* (Linne) var. *mendesi* Petri, 1955.

*Spiroloculina concava* Petri, **309,** p. 53, pl. 2, fig. 3–6, Miocene, Brazil, is preoccupied by *Spiroloculina acuta* Brady var. *concava* Wiesner, 1913, according to Heron-Allen and Earland, 1916, Trans. Linn. Soc. London (2), Zool., vol. 11, pt. 13, p. 208, pl. 39, fig. 1–3. Changed to *Spiroloculina henbesti* Petri, 1955.

*Textularia curta* Petri, **309,** p. 46, pl. 1, fig. 12. Miocene, Brazil, is preoccupied by *Textularia flintii* Cushman var. *curta* Cushman, 1922, Bull. U. S. Nat. Mus., vol. 104, p. 14, pl. 2, fig. 2,3; changed to *Textularia leinzi* Petri, 1955.

*Tritaxia spiritensis* Stelck and Wall subsp. *elongata* Stelck and Wall, **361,** p. 32, pl. 2, fig. 15, Upper Cretaceous of western Canada, is preoccupied by *Tritaxia elongata* Halkyard 1917, Manchester Lit. Phil. Soc., Proc. and Mem., vol. 62 (1917), Manchester 1919, p. 35, pl. 3, fig. 9 from the Eocene of Biarritz, France. Renamed: *Tritaxia spiritensis* Stelck and Wall subsp. *prolongata* Stelck and Wall, 1955.

*Vaginulina zaglobensis* Bielecka and Pozaryski var. *parallela* Bielecka and Pozaryski, **37,** p. 45, pl. 6, fig. 27 from Upper Jurassic of Poland is preoccupied by *Vaginulina recta* Reuss, 1863, var. *parallela* Halkyard, 1917, Mem. Proc. Manchester Lit. Phil. Soc., Manchester 1919, vol. 62, p. 82, pl. 5, fig. 5,6 from the Eocene of Biarritz, France.

### NOMINA NUDA 1954

Until evidence is available that the following names have duly been proposed in accordance with the International Rules of Zoological Nomenclature, they are, herewith, regarded as nomina nuda:

In Kihara, Murata and Sugahara, **222,** p. 457: *Gyroidina sechibaruensis* n. sp. and *Spiroplectammina kitamatsuraense* n. sp.

In Toriyama, **385,** on various pages: *Fusulinella subsphaerica* n.sp.; *Nankinella nagatoensis* n.sp.; *Parafusulina pseudojaponica* n. sp.; *Profusulinella beppensis* n. sp.; *Pseudofusulina vulgaris megasphaerica* n. var.; *Pseudofusulina kraffti magna* n. var.; *Staffella akagoensis* n. sp.; *Schwagerina okafujii* n. sp; *Schwagerina etoi* n. sp.; *Schwagerina kyowaensis* n. sp.; *Schwagerina japonica* n. sp.; *Triticites isaensis* n. sp.; *Triticites obai* n. sp.; *Triticites michiae* n. sp.; *Triticites tantula* n. sp.; *Triticites kuroiwaensis* n. sp., and *Yabeina pinguis* n. sp.

In Stelck and Wall, **361,** the following nomina nuda are listed:

*Ammobaculites gravenori, A. spiritensis, Ammomarginulina lorangerae, Dorothia kaskapauensis D. kaskapauensis* var. *gracilis, Flabellammina kaskapauensis, F. irenensis, F. warreni, F. webbi, Gaudryina irenensis, G. spiritensis, Haplophragmoides collyra* var. *bahani. H. pacalis, H. crickmayi, H. eocalcula, Spiroplectammina phauloides, Textularia gravenori, Trochammina rutherfordi, T. wetteri* and *Verneuilinoides perplexa* var. *gleddiei.* (*Note:* All these nomina nuda are validated by Stelck and Wall in 1955.)

### NOMENCLATURA APERTA 1954

*Alveolophragmium* sp. Parker, **305,** p. 488, pl. 1, fig. 22. Recent, Gulf of Mexico.

*Ammobaculites* n. sp. Emiliani, **126,** p. 106, pl. 21, fig. 2. Oligocene, Italy.

—— sp. A Parker, **305,** p. 489, pl. 2, fig. 7,8. Recent, Gulf of Mexico.

—— sp. B Parker, **305,** p. 489, pl. 2, fig. 6. Recent, Gulf of Mexico.

*Ammodiscus* sp. Wilson, **412,** p. 131, pl. 12, fig. 3. Oligocene, California.

*Ammoglobigerina* sp. Emiliani, **126,** p. 108, pl. 21, fig. 4. Oligocene, Italy.

*Ammovertella* sp. Emiliani, **126,** p. 109, pl. 21, fig. 5. Oligocene, Italy.

*Anomalina* Biswas, **39,** pl. 94, fig. 11. Eocene, Assam.

—— n. sp. 1 Emiliani, **126,** p. 110, pl. 21, fig. 8. Oligocene, Italy.

—— n. sp. 2 Emiliani, **126,** p. 110, pl. 21, fig. 6. Oligocene, Italy.

—— (*?*) sp. Kleinpell, **225,** p. 73, pl. 10, fig. 2. Neogene, Fiji.

*Archaias ?* sp. Todd and Post, **380,** p. 557, pl. 202, fig. 6,7. Miocene, Bikini.

*Bathysiphon ?* sp. Eisenack, **123,** p. 56, pl. 4, fig. 21. Silurian, Baltic States.

—— n. sp. 1 Emiliani, **126,** p. 112, pl. 21, fig. 10. Oligocene, Italy.

—— n. sp. 2 Emiliani, **126,** p. 112, pl. 21, fig. 9. Oligocene, Italy.

—— n. sp. 3 Emiliani, **126,** p. 112, pl. 21, fig. 11. Oligocene, Italy.

*Bigenerina* sp. Cushman, Todd and Post, **94,** p. 330, pl. 83, fig. 12. Recent, Marshall Islands.

—— sp. Fox, **142,** p. 112, pl. 24, fig. 9. Cretaceous, Dakota-Wyoming.

*Bitubulogenerina* sp. Cushman, Todd and Post, **94,** p. 354, pl. 88, fig. 11. Recent, Marshall Islands.

*Bolivina* sp. Chang, **70,** p. 113, pl. 3, fig. 12. Oligocene, Taiwan.

—— sp. Parker, **305,** p. 518, pl. 7, fig. 25. Recent, Gulf of Mexico.

—— sp. Petri, **309,** p. 94, pl. 7, fig. 5,6. Miocene, Brazil.
—— sp. "A" Boltovskoy, **46,** p. 283, pl. 26, fig. 9, Recent, off Argentina.
*Bolivinoides* sp. Reiss, **333,** p. 157, pl. 29, fig. 11. Cretaceous, Israel.
*Bulimina* sp. Chang, **70,** p. 113, pl. 3, fig. 9. Oligocene, Taiwan.
—— (*?*) sp. Wilson, **412,** p. 139, pl. 15, fig. 13. Oligocene, California.
*Carpenteria* sp. Cushman, Todd and Post, **94,** p. 373, pl. 82, fig. 15. Recent, Marshall Islands.
*Cassidulina* n. sp. Emiliani, **126,** p. 113, pl. 21, fig. 13. Oligocene, Italy.
*Cassidulinoides* sp. A Higuchi, **188,** Pliocene, Japan.
*Cibicides* n. sp. 1 Emiliani, **126,** p. 116, pl. 21, fig. 14. Oligocene, Italy.
—— n. sp. 2 Emiliani, **126,** p. 116, pl. 21, fig. 15. Oligocene, Italy.
—— n. sp. 3 Emiliani, **126,** p. 116, pl. 21, fig. 16. Oligocene, Italy.
—— (*?*) sp. Wilson, **412,** p. 145, pl. 17, fig. 9. Oligocene, California.
*Cibicidina* sp. Cushman, Todd and Post, **94,** p. 372, pl. 91, fig. 32. Recent, Marshall Islands.
—— n. sp. Emiliani, **126,** p. 117, pl. 21, fig. 17. Oligocene, Italy.
*Cibicidoides* sp. Kleinpell, **225,** p. 76, pl. 10, fig. 6. Neogene, Fiji.
*Clavulinoides* sp. Chang. **70,** p. 107, pl. 1, fig. 4,5. Oligocene, Taiwan.
*Conicospirillina* sp. Cushman, Todd and Post, **94,** p. 357, pl. 88, fig. 39. Recent, Marshall Islands.
*Cornuspira* sp. Petri, **309,** p. 58, pl. 2, fig. 20,21. Miocene, Brazil.
*Cribrobulimina ?* sp. Petri, **309,** p. 50, pl. 1, fig. 10,11. Miocene, Brazil.
*Cycloloculina* sp. Todd and Post, **380,** p. 564, pl. 200, fig. 6. Miocene, Bikini.
*Cymbalopora* sp. Kleinpell, **225,** p. 68, pl. 9, fig. 1. Neogene, Fiji.
*Dentalina* n. sp. Emiliani, **126,** p. 119, pl. 22, fig. 3. Oligocene, Italy.
—— sp. Fox, **142,** p. 116, pl. 25, fig. 15. Cretaceous, Dakota and Wyoming.
—— sp. Camacho, **65,** p. 33, pl. 5, fig. 4. Upper Cretaceous, Argentina.
—— sp. Camacho, **65,** p. 33, pl. 6, fig. 14. Upper Cretaceous, Argentina.
—— sp. A Puri, **326,** p. 100, pl. 6, fig. 6,7. Miocene, Florida.
—— sp. B Puri, **326,** p. 100, pl. 6, fig. 8,9. Miocene, Florida.
—— *?* sp. Chang, **70,** p. 111, pl. 2, fig. 20. Oligocene, Taiwan.
*Dentalinoides* sp. Emiliani, **126,** p. 119, pl. 22, fig. 5. Oligocene, Italy.
*Discorbis* sp. Petri, **309,** p. 101, pl. 8, fig. 11–13. Miocene, Brazil.
—— sp. "A" Boltovskoy, **45,** p. 203, pl. 15, fig. 4. Recent, off Argentina.
—— sp. "A" Boltovskoy, **46,** p. 286, pl. 27, fig. 2. Recent, off Argentina.
*Dorothia* n. sp. 1 Emiliani, **126,** p. 120, pl. 22, fig. 6. Oligocene, Italy.
—— n. sp. 2 Emiliani, **126,** p. 121, pl. 22, fig. 7 Oligocene, Italy.
—— n. sp. 3 Emiliani, **126,** p. 121, pl. 22, fig. 8. Oligocene, Italy.
*Dunbarula ?* sp. Kanmera. **217,** p. 7, pl. 3, fig. 8,?; 9–11,20. Permian, Japan.
*Dyocibicides* sp. Petri, **309,** p. 140, pl. 14, fig. 13–15. Miocene, Brazil.
*Ellipsoglandulina* n. sp. 1 Emiliani, **126,** p. 121, pl. 22, fig. 13. Oligocene, Italy.
—— n. sp. 2 Emiliani, **126,** p. 122, pl. 22, fig. 14. Oligocene, Italy.
—— n. sp. 3 Emiliani, **126,** p. 122, pl. 22, fig. 15, Oligocene, Italy.
*Ellipsolagena* n. sp. 1 Emiliani, **126,** p. 122, pl. 22, fig. 16. Oligocene, Italy.
—— n. sp. 2 Emiliani, **126,** p. 122, pl. 22, fig. 17. Oligocene, Italy.
—— n. sp. 3 Emiliani, **126,** p. 122, pl. 22, fig. 18. Oligocene, Italy.
—— n. sp. 4 Emiliani, **126,** p. 123, pl. 22, fig. 19, Oligocene, Italy.
—— n. sp. 5 Emiliani, **126,** p. 123, pl. 22, fig. 20. Oligocene, Italy.
*Ellipsolingulina* n. sp. Emiliani, **126,** p. 123, pl. 22, fig. 12. Oligocene, Italy.
*Ellipsonodosaria* (*?*) sp. Wilson, **412,** p. 141, pl. 16, fig. 6. Oligocene, California.
*Ellipsopleurostomella* (*?*) sp. Wilson, **412,** p. 141, pl. 16, fig. 5. Oligocene, California.
*Elphidium* sp. Petri, **309,** p. 81, pl. 6, fig. 1,2. Miocene, Brazil.
*Epistominella* sp. Cushman, Todd and Post, **94,** p. 365, pl. 90, fig. 21. Recent, Marshall Islands.
*Eponides* n. sp. 1 Emiliani, **126,** p. 125, pl. 22, fig. 22. Oligocene, Italy.
—— n. sp. 2 Emiliani, **126,** p. 126, pl. 22, fig. 23. Oligocene, Italy.
—— n. sp. 3 Emiliani, **126,** p. 126, pl. 23, fig. 1. Oligocene, Italy.
—— n. sp. 4 Emiliani, **126,** p. 126, pl. 23, fig. 2 Oligocene, Italy.
—— n. sp. 5 Emiliani, **126,** p. 126, pl. 23, fig. 3. Oligocene, Italy.
*Eponides* sp. Kleinpell, **225,** p. 60, pl. 4, fig. 4. Neogene, Fiji.
—— sp. Kleinpell, **225,** p. 60, pl. 6, fig. 2. Neogene, Fiji.
*Fissurina* n. sp. 1 Emiliani, **126,** p. 127, pl. 23, fig. 4. Oligocene, Italy.
—— n. sp. 2 Emiliani, **126,** p. 127, pl. 23, fig. 5. Oligocene, Italy.
—— n. sp. 3 Emiliani, **126,** p. 127, pl. 23, fig. 6. Oligocene, Italy.
—— sp. Petri, **309,** p. 68, pl. 4, fig. 1,2. Miocene, Brazil.
—— sp. "A" Boltovskoy, **46,** p. 270, pl. 23, fig. 1, Recent, off Argentina.
—— sp. A Cushman, Todd and Post, **94,** p. 351, pl. 87, fig. 23. Recent, Marshall Islands.
—— sp. B Cushman, Todd and Post, **94,** p. 352, pl. 87, fig. 33. Recent, Marshall Islands.
—— sp. C Cushman, Todd and Post, **94,** p. 352, pl. 87, fig. 34. Recent, Marshall Islands.
*Flabellammina* sp. 1 Fox, **142,** p. 111, pl. 24, fig. 6. Cretaceous, Dakota and Wyoming.

—— sp. 2 Fox, **142,** p. 111, pl. 24, fig. 7. Cretaceous, Dakota and Wyoming.
—— sp. 3 Fox, **142,** p. 111, pl. 24, fig. 8. Cretaceous Dakota and Wyoming.
*Flabellamminopsis tetracarinatus* Malecki var *α* Malecki, **251,** p. 109, pl. 5, fig. 11. Dogger, Poland.
—— *tricarinatus* Malecki vzr *α* Malecki, **251,** p. 108, pl. 5, fig. 4,5. Dogger, Poland.
—— —— —— var. *β* Malecki, **251,** p. 108, pl. 3, fig. 10; pl. 4, fig. 13,17,18; pl. 5, fig. 1. Dogger, Poland.
—— *variabilis* Malecki var. *α* Malecki, **251,** p. 106, pl. 4, fig. 10. Dogger, Poland.
—— —— —— var. *β* Malecki, **251,** p. 106, pl. 3, fig. 11; pl. 4, fig. 11. Dogger, Poland.
—— —— —— var. *γ* Malecki, **251,** p. 107, pl. 4, fig. 9. Dogger, Poland.
*Flintia ?* sp. Chang, **70,** p. 109, pl. 2, fig. 9. Oligocene, Taiwan.
*Frondicularia* sp. Fox, **142,** p. 118, pl. 26, fig. 7. Cretaceous, Dakota and Wyoming.
—— sp. Oberhauser, **296,** p. 204, text fig. 5. Liassic, Turkey.
—— sp. Oberhauser, **296,** p. 204, text fig. 5. Liassic, Turkey.
—— sp. Petri, **309,** p. 62, pl. 3, fig. 9. Miocene, Brazil.
*Fusulina* new species Alexander, **7,** p. 44, pl. 2, fig. 17. Pennsylvanian, Oklahoma.
—— sp. 1 Skinner and Wilde, **351,** p. 450, pl. 50, fig. 1,3,5. Permian, Texas.
—— sp. 2 Skinner and Wilde, **351,** p. 449, pl. 39, fig. 2,4. Permian, Texas.
—— sp. 3 Skinner and Wilde, **351,** p. 448, pl. 48, fig. 3,4. Permian, Texas.
*Fusulinella* new species Alexander, **7,** p. 18, pl. 1, fig. 4–7. Pennsylvanian, Oklahoma.
*Gaudryina (?)* sp. Wilson, **412,** p. 133, pl. 13, fig. 1. Oligocene, California.
*Globigerina* n. sp. 1 Emiliani, **126,** p. 130, pl. 23, fig. 8. Oligocene, Italy.
—— n. sp. 2 Emiliani, **126,** p. 130, pl. 23, fig. 7. Oligocene, Italy.
—— n. sp. 3 Emiliani, **126,** p. 131, pl. 23, fig. 9. Oligocene, Italy.
—— n. sp. 4 Emiliani, **126,** p. 131, pl. 23, fig. 11. Oligocene, Italy.
—— n. sp. 5 Emiliani, **126,** p. 131, pl. 23, fig. 12. Oligocene, Italy.
—— sp. Bolli, **43,** p. 2, text fig. 8. Pliocene, Panama.
—— sp. Petri, **309,** p. 122, pl. 12, fig. 8,9. Miocene, Brazil.
—— *?* sp. Cushman, Todd and Post, **94,** p. 368, pl. 91, fig. 3. Recent, Marshall Islands.
—— *(?)* sp. Kleinpell, **225,** p. 70, pl. 9, fig. 9. Neogene, Fiji.
*Globigerinoides* sp. Petri, **309,** p. 126, pl. 12, fig. 14. Miocene, Brazil.
*Globorotalia* Biswas, **39,** pl. 94, fig. 10. Eocene, Assam.
—— sp. Petri, **309,** p. 131, pl. 13, fig. 10,11. Miocene, Brazil.
*Globorotalites* n. sp. Emiliani, **126,** p. 131, pl. 23, fig. 13. Oligocene, Italy.
*Glomospira* n. sp. Emiliani, **126,** p. 135, pl. 24, fig. 1. Oligocene, Italy.
*Guttulina* sp. Wilson, **412,** p. 137, pl. 15, fig. 5. Oligocene, California.
*Gyroidina* n. sp. 1 Emiliani, **126,** p. 137, pl. 24, fig. 3. Oligocene, Italy.
—— n. sp. 2 Emiliani, **126,** p. 137, pl. 24, fig. 5. Oligocene, Italy.
—— n. sp. 3 Emiliani, **126,** p. 138, pl. 24, fig. 7. Oligocene, Italy.
—— n. sp. 4 Emiliani, **126,** p. 138, pl. 24, fig. 8. Oligocene, Italy.
—— n. sp. 4 Emiliani, **126,** p. 138, pl. 24, fig. 8. Oligocene, Italy.
*Gyroidinoides* sp. Teri, **309,** p. 109, pl. 9, fig. 4–6. Miocene, Brazil.
*Haplophragmoides* n. sp. 1 Emiliani, **126,** p. 141, pl. 24, fig. 9. Oligocene, Italy.
—— n. sp. 2 Emiliani, **126,** p. 141, pl. 24, fig. 10. Oligocene, Italy.
—— n. sp. 3 Emiliani, **126,** p. 141, pl. 24, fig. 11. Oligocene, Italy.
—— sp. Fox, **142,** p. 111, pl. 24, fig. 4,5. Cretaceous, Dakota and Wyoming.
—— sp. Wilson, **412,** p. 131, pl. 12, fig. 4. Oligocene, California.
*Heronallenia* sp. Cushman, Todd and Post, **94,** p. 359, pl. 89, fig. 18. Recent, Marshall Islands.
*Hormosina* sp. Parker, **305,** p. 484, pl. 1, fig. 8. Recent, Gulf of Mexico.
*Karreriella* sp. Chang, **70,** p. 108, pl. 1, fig. 20. Oligocene, Taiwan.
*Lagena* n. sp. 1 Emiliani, **126,** p. 144, pl. 24, fig. 13. Oligocene, Italy.
—— n. sp. 2 Emiliani, **126,** p. 144, pl. 24, fig. 14. Oligocene, Italy.
—— n. sp. 3 Emiliani, **126,** p. 144, pl. 24, fig. 15. Oligocene, Italy.
—— sp. Camacho, **65,** p. 33, pl. 6, fig. 7. Upper Cretaceous, Argentina.
—— sp. Petri, **309,** p. 64, pl. 3, fig. 14,15. Miocene, Brazil.
*Laticarinina* sp. Petri, **309,** p. 134, pl. 14, fig. 8,9. Miocene, Brazil.
*Lenticulina* Biswas, **39,** pl. 94, fig. 6,7. Eocene, Assam.
—— species Feyling-Hanssen, **136,** p. 191, pl. 1, fig. 11–13. Pleistocene, Norway.
*Loxostomum ?* sp. Camacho, **65,** p. 34, pl. 6, fig. 22. Upper Cretaceous, Argentina.
*Marginulina* Biswas, **39,** pl. 94, fig. 8,9. Eocene, Assam.
—— sp. Oberhauser, **296,** p. 204, fig. 6. Liassic, Turkey.
—— sp. 1 Fox, **142,** p. 115, pl. 25, fig. 11. Cretaceous, Dakota and Wyoming.
—— sp. 2 Fox, **142,** p. 115, pl. 25, fig. 10,12. Cretaceous, Dakota, Wyoming.
*Nankinella* sp. Thompson, **373,** p. 32, pl. 5, fig. 10. Permian, Nevada.
*Nodosarella* n. sp. 1 Emiliani, **126,** p. 146, pl. 22, fig. 21. Oligocene, Italy.
—— n. sp. 2 Emiliani, **126,** p. 146, pl. 24, fig. 16. Oligocene, Italy.
*Nodosaria* n. sp. 1 Emiliani, **126,** p. 149, pl. 24, fig. 17. Oligocene, Italy.

—— n. sp. 2 Emiliani, **126,** p. 149, pl. 24, fig. 18. Oligocene, Italy.
—— sp. A Cushman, Todd and Post, **94,** p. 344, pl. 86, fig. 11. Recent, Marshall Islands.
—— sp. B Cushman, Todd and Post, **94,** p. 344, pl. 86, fig. 12. Recent, Marshall Islands.
—— sp. C Cushman, Todd and Post, **94,** p. 344, pl. 86, fig. 13. Recent, Marshall Islands.
*Nonion* n. sp. 1 Emiliani, **126,** p. 150, pl. 24, fig. 19. Oligocene, Italy.
—— n. sp. 2 Emiliani, **126,** p. 150, pl. 24, fig. 20. Oligocene, Italy.
—— n. sp. 3 Emiliani, **126,** p. 150, pl. 24, fig. 21. Oligocene, Italy.
*Nonionella* n. sp. Emiliani, **126,** p. 150, pl. 25, fig. 1. Oligocene, Italy.
—— sp. Bowen, **51,** p. 162, pl. C, fig. 10,11. Eocene, England.
—— sp. Weiss, **407,** p. 158, pl. 32, fig. 4. Pleistocene, New York.
—— sp. B Cushman, Todd and Post, **94,** p. 345, pl. 86, fig. 28, Recent, Marshall Islands.
*Nouria* sp. Parker, **305,** p. 504, pl. 5, fig. 20. Recent, Gulf of Mexico.
*Operculina* sp. Smout, **355,** p. 75, pl. 13, fig. 8–12; pl. 14, fig. 1. Paleocene, Qatar.
—— (*?*) sp. Kleinpell, **255,** p. 47, pl. 3 fig. 3. Neogene, Fiji.
*Palmula* sp. Fox, **142,** p. 117, pl. 26, fig. 1. Cretaceous, Dakota and Wyoming.
—— *?* Fox, **142,** p. 117, pl. 26, figs. 2,3. Cretaceous, Dakota and Wyoming.
*Parafissurina* sp. Cushman, Todd and Post, **94,** p. 356, pl. 88, fig. 25, Recent, Marshall Islands.
*Parafusulina ?* sp. Kanmera, **217,** p. 11, pl. 1, fig. 1–5. Permian, Japan.
*Pegidia* (*?*) sp. Kleinpell, **225,** p. 62, pl. 6, fig. 8. Neogene, Fiji.
*Peneroplis* sp. Cushman, Todd and Post, **94,** p. 238, pl. 87. fig. 3. Recent, Marshall Islands.
*Planularia* sp. Chang, **70,** p. 111, pl. 2, fig. 18. Oligocene, Taiwan.
—— sp. Fox, **142,** p. 114, pl. 25, fig. 6. Cretaceous, Dakota and Wyoming.
*Planulina* sp. Kleinpell, **225,** p. 74, pl. 10, fig. 4. Neogene, Fiji.
—— sp. Petri, **309,** p. 134, pl. 13, fig. 12–14. Miocene, Brazil.
*Pleurostomella* n. sp. 1 Emiliani, **126,** p. 151, pl. 25, fig. 2. Oligocene, Italy.
—— n. sp. 2 Emiliani, **126,** p. 152, pl. 25, fig. 3. Oligocene, Italy.
—— n. sp. 3 Emiliani, **126,** p. 152, pl. 25, fig. 4. Oligocene, Italy.
*Polymorphina* n. sp. Emiliani, **126,** p. 152, p. 25, fig. 5. Oligocene, Italy.
*Proteonina* n. sp. Emiliani, **126,** p. 152, pl. 25, fig. 6. Oligocene, Italy.
—— sp. Cushman, Todd and Post, **94,** p. 328, pl. 83, fig. 1. Recent, Marshall Islands.
*Pseudobulimina* sp. Cushman, Todd, and Post, **94,** p. 350, pl. 87, fig. 20. Recent, Marshall Islands.
*Pseudodoliolina* n. sp. Kanmera, **217,** p. 14, pl. 2, fig. 7,8. Permian, Japan.
*Pseudoparrella* n. sp. Emiliani, **126,** p. 153, pl. 25, fig. 7. Oligocene, Italy.
*Pseudopolymorphina* sp. Petri, **309,** p. 70, pl. 4, fig. 6–8. Miocene, Brazil.
*Pullenia* n. sp. Emiliani, **126,** p. 155, pl. 25, fig. 8. Oligocene, Italy.
—— sp. Parker, **305,** p. 538, pl. 11, fig. 20,24. Recent, Gulf of Mexico.
*Pyrgo* sp. Chang, **70,** p. 109, pl. 2, fig. 7. Oligocene, Taiwan.
—— sp. Cushman, Todd and Post, **94,** p. 241, pl. 85, fig. 26. Recent, Marshall Islands.
—— sp. Feyling-Hanssen, **135,** p. 128, pl. 1, fig. 5. Pleistocene, Norway.
*Quinqueloculina* sp. Parker, **305,** p. 498, pl. 4, fig. 11,12. Recent, Gulf of Mexico.
—— sp. Petri, **309,** p. 53, pl. 1, fig. 24; pl. 2, fig. 1,2. Miocene, Brazil.
—— sp. "A" Boltovskoy, **45,** p. 126, pl. 1, fig. 11. Recent, off Argentina.
*Rauserella* sp. Kanmera, **217,** p. 4, pl. 3, fig. 13. Permian, Japan.
*Reusella* sp. A Cushman, Todd, and Post, **94,** p. 354, pl. 88, fig. 3. Recent, Marshall Islands.
—— sp. A Todd and Post, **380,** p. 559, pl. 199, fig. 9. Oligo-Miocene, Bikini.
—— sp. B Todd and Post, **380,** p. 559, pl. 199, fig. 10. Miocene, Bikini.
—— sp. C. Todd and Post, **94,** p. 559, pl. 199, fig. 11. Plio-Pleistocene, Bikini.
*Rhabdammina* n. sp. Emiliani, **126,** p. 158, pl. 25, fig. 10. Oligocene, Italy.
—— (*?*) sp. Wilson, **412,** p. 131, pl. 12, fig. 1. Oligocene, California.
*Reophax* sp. Parker, **305,** p. 484, pl. 1, fig. 12. Recent, Gulf of Mexico.
*Robulus* sp. Fox, **142,** p. 114, pl. 25, fig. 5. Cretaceous, Dakota and Wyoming.
—— sp. Wilson, **412,** p. 135, pl. 14, fig. 4. Oligocene, California.
—— sp. A Cushman, Todd and Post, **94,** p. 343, pl. 86, fig. 6. Recent, Marshall Islands.
—— sp. B Cushman, Todd and Post, **94,** p. 343, pl. 86, fig. 5. Recent, Marshall Islands.
—— sp. C Cushman, Todd and Post, **94,** p. 343, pl. 86, fig. 8. Recent, Marshall Islands.
—— sp. D Cushman, Todd and Post, **94,** p. 343, pl. 82, fig. 3. Recent, Marshall Islands.
—— *?* sp. Chang, **70,** p. 111, pl. 2, fig. 17. Oligocene, Taiwan.
*Rotorbinella* sp. Todd and Post, **380,** p. 562, pl. 200, fig. 2. Miocene, Bikini.
*Sigmoilina* sp. Parker, **305,** p. 499, pl. 5, fig. 1; text fig. 2. Recent, Gulf of Mexico.
*Siphonodosaria appendiculata* (Costa) var. nov. Emiliani, **126,** p. 159, pl. 25, fig. 12. Oligocene, Italy.
—— *subrotundata* (Herrmann) n. var. Emiliani, **126,** p. 161, pl. 25, fig. 13. Oligocene, Italy.
*Spirolina* sp. Petri, **309,** p. 83, pl. 6, fig. 8,9. Miocene, Brazil.
—— sp. Todd and Post, **380,** p. 557, pl. 199, fig. 2. Miocene, Bikini.
*Spiroloculina* sp. A Cushman, Todd and Post, **94,** p. 336, pl. 84, fig. 21,22. Recent, Marshall Islands.
—— sp. B Cushman, Todd and Post, **94,** p. 336, pl. 84, fig. 19. Recent, Marshall Islands.

*Spirophthalmidium* sp. Chang, **70,** p. 109, pl. 2, fig. 8. Oligocene, Taiwan.
*Spiroplectammina* sp. Wilson, **412,** p. 132, pl. 12, fig. 7. Oligocene, California.
*Taberina* sp. Petri, **309,** p. 85, pl. 6, fig. 10. Miocene, Brazil.
*Textularia* sp. Petri, **309,** p. 48, pl. 1, fig. 5. Miocene, Brazil.
—— (?) sp. Wilson, **412,** p. 133, pl. 12, fig. 8. Oligocene, California.
*Thurammina ?* sp. Form B Eisenback, **123,** p. 65, pl. 4, fig. 14–16. Silurian pebble. Baltic States.
*Trochammina* n. sp. 1 Emiliani, **126,** p. 163, pl. 25, fig. 16. Oligocene, Italy.
—— n. sp. 2 Emiliani, **126,** p. 164, pl. 25, fig. 17. Oligocene, Italy.
—— n. sp. 3 Emiliani, **126,** p. 164, pl. 25, fig. 18. Oligocene, Italy.
*Triloculina* sp. Petri, **309,** p. 56, pl. 2, fig. 10–12. Miocene, Brazil.
—— sp. A Cushman, Todd and Post, **94,** p. 340, pl. 85, fig. 20. Recent, Marshall Islands.
—— sp. B. Cushman, Todd and Post, **94,** p. 340, pl. 85, fig. 21. Recent, Marshall Islands.
—— sp. "A" Boltovskoy, **45,** p. 137, pl. 4, fig. 1. Recent, off Argentina.
—— sp. "A" Boltovskoy, **46,** p. 265, pl. 22, fig. 6. Recent, off Argentina.
—— sp. 1 Fox, **142,** p. 112, pl. 24, fig. 11–13. Cretaceous, Dakota and Wyoming.
—— sp. 2 Fox, **142,** p. 113, pl. 24, fig. 14–16. Cretaceous, Dakota and Wyoming.
—— sp. 3 Fox, **142,** p. 113, pl. 24, fig. 17–19. Cretaceous, Dakota and Wyoming.
*Uvigerina* sp. Petri, **309,** p. 96, pl. 7, fig. 9,10. Miocene, Brazil.
*Vaginulina* sp. Chang, **70,** p. 111, pl. 2, fig. 19. Oligocene, Taiwan.
—— sp. "A" Boltovskoy, **45,** p. 148, pl. 5, fig. 8. Recent, off Argentina.
—— sp. 1 Fox, **142,** p. 116, pl. 25, fig. 21. Cretaceous, Dakota and Wyoming.
—— sp. 2 Fox, **142,** p. 117, pl. 25, fig. 19,20. Cretaceous, Dakota and Wyoming.
*Valvulineria* (?) sp. Kleinpell, **225,** p. 58, pl. 5, fig. 7. Neogene, Fiji.
—— (?) sp. Wilson, **412,** p. 142, pl. 3, fig. 8. Oligocene, California.
*Verbeekina ?* n. sp. Kanmera, **217,** p. 15, pl. 2, fig. 9. Permian, Japan.
*Virgulina* species Feyling-Hanssen, **136,** p. 193, pl. 1, fig. 23,24. Pleistocene, Norway.

SUPPLEMENT FOR THE YEAR 1948

*Ticinella gaultina* Morosova, Bjull, Moskov. obshch. ispijtatel Prirody, vol. 23, No. 3, 1948, p. 41, pl. 2, fig. 16–18. Cenomanian, U.S.S.R.

SUPPLEMENT FOR THE YEAR 1950

OBSOLETES gen. nov. Kireeva, **423,** A new genus of the family Fusulinidae. Genotype: not known to compiler, as publication not available. Middle Carboniferous.

SUPPLEMENT TO THE YEAR 1951

In a publication by Dalmatskaya (title not known to the compiler), in : Moskov. obsh. ispijtatel Prirody, Bjull., 1951, pp. 194–196, the following new genus was proposed:
VERELLA gen. nov. Dalmatskaya, a new genus of the family Fusulinidae from the Russian Middle Carboniferous, with genotype:
—— *warsanofieve* Dalmatskaya, and another species:
—— *spicata* Dalmatskaya.

SUPPLEMENT FOR THE YEAR 1952

The following new forms are all described and figured in Voloshina and Dain, **439,** from Russia:
*Allomorphina marmaroschensis* Dain, p. 120, pl. 1, fig. 5,6. Miocene.
*Cassidulina caucasica* Subbotina, p. 100, pl. 4, fig. 4. Eocene.
—— *complanata* Voloshinova, p. 95, pl. 4, fig. 7. Miocene.
—— *curvicamerata* Voloshina, p. 92, pl. 2, fig. 9. Miocene.
—— *excavata* Voloshinova, p. 96, pl. 3, fig. 1. Oligo-Miocene. (*Note:* Kleinpell's *Cassidulina pulchella* Orbigny, Miocene Stratigr. of California, 1938, p. 335, pl. 10, fig. 9 is regarded as a synonym of this new species).
—— *laticamerata* Voloshinova, p. 95, pl. 4, fig. 7. Miocene. (Published in 1939?)
—— *limbata* Cushman and Hughes, 1925, var. *monstruosa* Voloshinova, p. 94, pl. 3, fig. 5. Miocene.
—— *magna* Voloshinova, p. 83, pl. 1, fig. 8. Miocene.
—— *miocenica* Voloshinova and Borovleva, p. 96, pl. 3, fig. 6. Miocene.
—— —— —— var. *carinata* Voloshinova, p. 97, pl. 3, fig. 7. Miocene. (*Note:* preoccupied by *Cassidulina smechovi carinata* Voloshinova, *ut infra.*)
—— —— —— var. *crassa* Voloshinova, p. 98, pl. 3, fig. 8. Miocene. (*Note:* preoccupied by d'Orbigny, 1839).
—— *pygmaea* Voloshinova, p. 100, pl. 5, fig. 3. Miocene.
—— *smechovi* Voloshinova, p. 90, pl. 2, fig. 1,2. Miocene.
—— —— —— var. *carinata* Voloshinova, p. 91, pl. 2, fig. 4. Miocene, (Pre-occupied by Silvestri, 1896, and by Cushman, 1922.)
—— —— —— var. *umbonata* Voloshinova, p. 91, pl. 2, fig. 5. Miocene.
—— —— —— var. *sulcata* Voloshinova, p. 91, pl. 2, fig. 3. Miocene.
CASSIDULINITA gen. nov. Suzin, p. 102. New genus of the family Cassidulinidae. Genotype: *Cassidulinita prima* Suzin, *ut. infra.* Pliocene.
—— *prima* Suzin, p. 103, pl. 4, fig. 12,13. Pliocene, Caucasus region.
*Chilostomella azerbaidjanica* Chalilov, p. 124, pl. 2, fig. 2. Eocene.
—— *balkhanensis* Dain and Chalikov, p. 125, pl. 2, fig. 3,4. Eocene-Oligocene.
*Elphidium jannae* Voloshinova and Borovleva, p. 52, pl. 7, fig. 2–4. Miocene.
—— *katangliense* Voloshinova and Borovleva, p. 38, pl. 5, fig. 11,12. Miocene.
—— *lautenschlägeri* Voloshinova, p. 49, pl. 6, fig. 3. Miocene.

—— *macellum* (Fichtel and Moll) var. *maeotica* Gherke, p. 45, pl. 5, figs. 5,6. Maeotian.
—— *mironovi* Voloshinova, p. 43, pl. 5, fig. 1. Pliocene.
—— *nabilense* Voloshinova and Borovleva, p. 49, pl. 6, fig. 5. Miocene.
—— *noniformis* Gerke, p. 51, pl. 6, fig. 6–8. Maeotian.
—— *nutovoense* Borovleva, p. 52, pl. 7, fig. 6. Pliocene.
—— *orientale* Voloshina, p. 38, pl. 4, fig. 1. Miocene and Pliocene. (published in 1939?)
—— *rugosum* (Orbigny) var. *atschiensis* Suzin, p. 46, pl. 5, fig. 8. Miocene.
—— *sachalinense* Voloshinova, p. 55, pl. 9, fig. 1. Miocene.
—— *tenerum* Voloshinova, p. 54, pl. 8, fig. 10. Miocene.
—— *vulgare* Voloshinova, p. 53, pl. 8, fig. 3–9. Miocene.
*Nonion anomalinoides* Gerke, p. 21, pl. 1, fig. 10. Maetian.
—— *bogdanowiczi* Voloshinova, p. 19, pl. 1, fig. 7,8. Miocene.
—— *matchigaricus* Voloshinova, p. 22, pl. 1, fig. 11. Miocene.
—— *subbotinae* Chutzieva, p. 26, pl. 2, fig. 10. Miocene.
*Nonionella bykovae* Voloshinova, p. 30, pl. 3, fig. 4. Paleocene.
—— *kalinini* Voloshinova, p. 29, pl. 3, fig. 6. Maestrichtian.
*Notorotalia clarki* Voloshinova, p. 56, pl. 9, fig. 2. Miocene. For: *Rotalia beccarii* Linné in Clark, 1906, Maryland Geol. Surv., p. 215, pl. 66, fig. 11–13.
PSEUDOPARELLINAE subfam. nov. Voloshinova, p. 81, New subfamily of the family Cassidulinidae. Includes the genus *Pseudoparella* (sic!) Cushman and Dam, 1948.
*Pseudoparella granulosa* Bykova, p. 83, pl. 1, fig. 3. Paleocene.
—— *suzini* Chutzieva, p. 84, pl. 1, fig. 2. Miocene.
*Pullenia dampelae* Dain, p. 134, pl. 4, fig. 1–3. Senonian. For: *Pullenia quinqueloba* Reuss in Plummer, 1926, Univ. Texas Bull. 2644, p. 136. pl. 8, fig. 12; and for: *Pullenia cretacea* Cushman, 1937, Contr. Cushman Lab. Foram. Research, vol. 12, p. 75, pl. 13, fig. 8.
—— *ksakhstanica* Dain, p. 131, pl. 3, fig. 3. Senonian.
—— *sexacamerata* Pischvanova, p. 133, pl. 3, fig. 7. Miocene.

SUPPLEMENT NOMENCLATURA APERTA 1952

*Anomalina* sp. Carvalho and Chermont, **430,** p. 95, pl. 1, fig. 19. Recent, off Brazil.
*Discorbis* sp. Carvalho and Chermont, **430,** p. 94, pl. 1, fig. 17. Recent, off Brazil.
*Nummulites* sp. Ruiz de Gaona, **436,** p. 80, pl. 19, fig. 3. Eocene, Spain.
—— sp. Ruiz de Gaona, **436,** p. 80, pl. 19, fig. 19. Eocene, Spain.
—— sp. Ruiz de Gaona, **436,** p. 80, pl. 21, fig. 45. Eocene, Spain.
—— sp. Ruiz de Gaona, **436,** p. 80, pl. 32, fig 52,53. Eocene, Spain.

SUPPLEMENT FOR THE YEAR 1953

ACARININA gen. nov. Subbotina, **505,** p. 219. New genus of the family Globorotaliidae. Genotype: *Acarinina acarinata* Subbotina, 1953, *ut infra*. Paleocene; Eocene.
—— *acarinata* Subbotina, **505,** p. 229, pl. 22, fig. 4–10. Paleocene, USSR.
—— *intermedia* Subbotina, **505,** p. 227, pl. 20, fig. 1–4, 14–16. Paleocene, USSR.
—— *interposita* Subbotina, **505,** p. 231, pl. 23, fig. 6,7. Lower Eocene, USSR.
—— *pseudotopilensis* Subbotina, **505,** p. 227, pl. 8,9; pl. 22, fig. 1–3. Paleocene and Lower Eocene, USSR.
—— *rotundimarginata* Subbotina, **505,** p. 234, pl. 25, fig. 1–3. Upper Eocene, USSR.
—— *rugosoaculeata* Subbotina, **505,** p. 235, pl. 25, fig. 4–6. Upper Eocene, USSR.
—— *triplex* Subbotina, **505,** p. 230, pl. 23, fig. 1–5. Lower Eocene, USSR.
*Ammobaculites manyschensis* Bykova, **447,** p. 58, pl. 1, fig. 2,3. Paleocene-Eocene, Central Asia. For: *Ammobaculties midwayensis* Plummer in Cushman, 1940, Contr. Cushman Lab. Foram. Research, vol. 16, p. 52, pl. 9, fig. 1,2. (*Note:* Plummer's species has been renamed *Ammobaculites paleocenicus* Cushman, 1947; Bykova's new species is, therefore, a synonym of *A. paleocenicus* Cushman.)
*Anomalina pompilioides* Galloway and Heminway, 1941, var. *semicribrata* Beckmann, **443,** p. 400, pl. 27, fig. 3. Middle Eocene to Lower Oligocene, Barbados.
AUERINELLA gen. nov. Frenguelli, **453,** p. 46. New genus of "incertae sedis." Genotype: *Auerinella fuegiae* Frenguelli, 1953, *ut infra*. Post-Glacial.
—— *fuegiae* Frenguelli, **453,** p. 46, text fig. 4-B.5. Post-Glacial, Argentina.
*Baggina notoensis* Asano, Short Papers No. 5, Inst. Geol. Paleont. Tohoku Univ. Sendai, p. 10, pl. 3, fig. 17. Miocene, Japan.
*Bitubulogenerina dertonensis* Gianotti, **455,** p. 271, pl. 12, fig. 12. Miocene, Italy.
*Bolivina petterssoni* Parker, **486,** p. 36, pl. 7, fig. 15–17. Recent, North Atlantic 4940 m.
*Bulimina translucens* Parker, **486,** p. 33, pl. 6, fig. 30,31. Recent, North Atlantic, 4181 m.
CANALIFERA gen. nov. Krasheninnikov, **472,** pp. 88–89, New genus of the family Canaliferidae (group of Nonionidae). Publication not seen by compiler.
CANALIFERIDAE fam. nov. Krasheninnikov, **472,** pp. 88–89. Publication not seen by compiler.
CARPENTERELLA gen. nov. Krasheninnikov, **472,** pp. 88–89. New genus of the family Nonionidae. Publication not seen by compiler. (*Note:* Preoccupied by Collenette, 1933, a lepidopteran genus.)
*Chrysalidinella ruscelli* Gianotti, **455,** p. 261, pl. 12, fig. 6. Miocene, Italy.
*Cibicides kullenbergi* Parker, **486,** p. 49, pl. 11, fig. 7,8. Recent, North Atlantic, 3109 m.

—— *mexicanus* Nuttall, 1932, var. *miocenicus* Ruscelli, **494,** p. 158, pl. 7, fig. 1,3. Miocene, Italy. (*Note:* Preoccupied by *Cibicides floridanus* (Cushman, 1918) var. *miocenicus* Colom, 1945, Inst. Geol. Lucas Mallada, Madrid, Estud. Geol. No. 3, p. 173, pl. 14, fig. 291,295–297,300,303; pl. 12, fig. 248, from the Vindobonian of Mallorca.)

—— *succedens* Brotzen, 1948, var. *rigida* Bykova, **447,** p. 96, pl. 5, fig. 4. Paleocene-Eocene, Central Asia.

—— *suzakensis* Bykova, **447,** p. 99, pl. 5, fig. 5. Paleocene-Eocene, Central Asia.

*Dorothia ashiyaensis* Murata, **478,** p. 6, pl. 1, fig. 3. Oligocene, Japan.

*Ehrenbergina pacifica* Cushman var. *basispinosa* Gianotti, **455,** p. 281, pl. 16, fig. 3. Tortonian, Italy.

—— *undulata* Parker, **486,** p. 46, pl. 10, fig. 14–16. Recent, North Atlantic, 1955 m. (For synonymy see original publication).

*Ellipsopleurostomella oligocenica* Napoli Alliata, **480,** p. 67, pl. 1, fig. 17. Upper Oligocene, Italy.

ELPHIDIIDAE fam. nov. Krasheninnikov, **472,** pp. 88–89. Publication not seen by compiler.

*Eponides saginaris* Bykova, **447,** p. 80, pl. 3, fig. 3. Paleocene-Eocene, Central Asia.

*Gaudryina ashiyaensis* Murata, **478,** p. 6, pl. 1, fig. 4. Oligocene, Japan.

*Globigerina bulloides* Orbigny, 1826, var. *compacta* Subbotina, **505,** p. 76, pl. 9, fig. 4. Upper Eocene, USSR. (*Note:* Preoccupied by *G. pseudoecocaena* Subbotina var. *compacta* Subbotina, 1953, *ut infra.*)

—— *corpulenta* Subbotina, **505,** p. 76, pl. 9, fig. 5–7; pl. 10, fig. 1–4. Upper Eocene, USSR.

—— *edita* Subbotina, **505,** p. 54, pl. 2, fig. 1. Paleocene, USSR.

—— *eocaenica* Terquem, 1882, var. *irregularis* Subbotina, **505,** p. 81, pl. 11, fig. 12–14. Upper Eocene, USSR.

—— *frontosa* Subbotina, **505,** p. 84, pl. 12, fig. 3–7. Eocene, USSR.

—— *hoterivica* Subbotina, **505,** p. 50, pl. 1, fig. 1–4. Cretaceous, USSR.

—— *inaequispira* Subbotina, **505,** p. 69, pl. 6, fig. 1–4. Eocene, USSR.

—— *inconstans* Subbotina, **505,** p. 58, pl. 3, fig. 1,2. Paleocene, USSR.

—— *kelleri* Subbotina, **505,** p. 54, pl. 1, fig. 16. Cretaceous, USSR.

—— *moskvini* Shuckaja, **499,** p. 74, text fig. 1, No. 1–9; text fig. 2, No. 15, 16, Danian, Caucasus region.

—— *officinalis* Subbotina, **505,** p. 78, pl. 11, fig. 1–7. Topmost Eocene and basal Oligocene, USSR.

—— *pseudoecocaena* Subbotina, **505,** p. 66, pl. 4, fig. 9; pl. 5, fig. 1,2,6. Eocene, USSR.

———— var. *compacta* Subbotina, **505,** p. 68, pl. 5, fig. 3.4. Upper Eocene, USSR.

———— var. *trilobata* Subbotina, **505,** p. 68, pl. 5, fig. 5. Eocene, USSR. (*Note:* Preoccupied by Costa, 1856, Atti Accad. Pont., vol. 7, No. 2, p. 241, pl. 21, fig. 4.)

—— *trivialis* Subbotina, **505,** p. 64, pl. 4, fig. 4–8. Maestrichtian to Danian, USSR.

—— *varianta* Subbotina, **505,** p. 63, pl. 3, fig. 5–10,11,12; pl. 4, fig. 1–3; pl. 16. fig. 1–3. Paleocene and Lower Eocene, USSR.

*Globigerinoides rubriformis* Subbotina, **505,** p. 92, pl. 13, fig. 19; pl. 14, fig. 6–9. Eocene, USSR.

*Globorotalia convexa* Subbotina, **505,** p.p. 209, pl. 17, fig. 2,3. Paleocene and Lower Eocene, USSR.

—— *imitata* Subbotina, **505,** p. 206, pl. 16, fig. 14–16. Paleocene, USSR.

—— *lensiformis* Subbotina, **505,** p. 214, pl. 18, fig. 4,5. Upper Eocene, USSR.

—— *marginodendata* Subbotina, **505,** p. 212. Lower Eocene, USSR. For: *Globorotalia crassata* Cushman in Glaessner, 1937, Probl. of Micropal., vol. 1, No. 1, p. 31, pl. 1, fig. 7.

—— *planoconica* Subbotina, **505,** p. 210, pl. 17, fig. 4–6. Paleocene, Lower Eocene, USSR.

—— *tadjikistanensis* Bykova, **447,** p. 86, pl. 3, fig. 5. Paleocene, USSR.

*Globotruncana fundiconulosa* Subbotina, **505,** p. 200, pl. 14, fig. 1–4; pl. 15, fig. 1,2. Senonian, USSR.

*Gyroidina cetera* Bykova, **447,** p. 77, pl. 3, fig. 1. Paleocene and Eocene, Central Asia.

—— *depressaeformis* Bykova, **447,** p. 78, pl. 3, fig. 2. Paleocene and Eocene, Central Asia. For: *Gyroidina depressa* Alth in Cushman and Renz, 1946, Spec. Publ. 18, Cushman Lab. Foram. Res., p. 44, pl. 7, fig. 16,17.

*Haplophragmoides fistulosus* Bykova, **447,** p. 57, pl. 1, fig. 1. Paleocene-Lower Eocene, Central Asia.

*Hauerina lyra* Serova, **498,** p. 62. Publication not seen by compiler.

—— *podolica* Serova, **498,** pp. 62–64. Publication not seen by compiler.

*Heronallenia desioi* Ruscelli, **494,** p. 147, pl. 5, fig. 7. Helvetian, Italy.

*Marginulina ashiyaensis* Murata, **478,** p. 6, pl. 1, fig. 7. Oligocene, Japan.

*Pleurostomella rameroensis* Napoli Alliata, **480,** p. 72, pl. 2, fig. 9,10. Upper Oligocene, Italy.

*Pseudorbitoides longispiralis* Papp and Küpper, **483,** p. 352, pl. 2, fig. 3. Campanian, Carinthia.

PSEUDOTEXTULARIELLA gen. nov. Barnard, Quart. Jour. Geol. Soc. London, vol. 109, pt. 2, p. 198. New genus of the family Valvulinidae. Genotype: *Textulariella cretosa* Cushman, 1932, Contr. Cushman Lab. Foram. Res., vol. 8, p. 97, pl. 11, fig. 17–19. Upper Cretaceous.

*Pyrulinoides antilleanus* Beckmann, **443,** p. 361, pl. 20, fig. 19–21; text fig. 8. Middle Eocent to Lower Oligocene, Barbados. (Published May 30, 1954).

*Quinqueloculina padana* Perconig, Consigl. Nazion. Ricerche, Contr. Sci. Geol. vol. 3, p. 95, text figs. 1–4. Upper Pliocene, Italy.

*Robulus ashiyaensis* Murata, **478,** p. 6, pl. 1, fig. 10. Oligocene, Japan.

—— *bertraneui* Glaçon, and Magné, **457,** p. 134, text fig. 1. Miocene and Pliocene, Algeria.

—— *infrasuzakensis* Bykova, **447,** p. 65, pl. 2, fig. 2. Paleocene-Eocene, USSR.

ROTUNDINA gen. nov. Subbotina, **505,** p. 164. New genus of the family Globorotaliidae. Genotype: *Globotruncana stephani* Gandolfi,

1942, Riv. Ital. Paleont. vol. 48, p. 130, pl. 3, fig. 4,5; pl. 4, fig. 36,37,41–44; pl. 6, fig. 4; pl. 9, fig. 8; pl. 14, fig. 2. Cenomanian to Maestrichtian.

—— *ordinaria* Subbotina, **505,** p. 166, pl. 3, fig. 3–9; pl. 4, fig. 1–9. Maestrichtian, USSR. For: *Globotruncana globigerinoides* Brotzen, 1936, Sverig. geol. Undersökn. ser. C, No. 396, Arsb. 30, No. 3, p. 177, pl. 12, fig. 3; pl. 13, fig. 3.

*Sphaeroidinella senni* Beckmann, **443,** p. 394, pl. 26, fig. 2–4; text fig. 20. Topmost Middle Eocene to Upper Eocene, Barbados. (Published May 30, 1954).

*Spiroplectammina monetalis* Bykova, **447,** p. 60, pl. 1, fig. 4. Paleocene-Eocene, USSR.

*Subalveolina perebaskini* Reichel, **492,** p. 257, pl. 13, fig. 1,2; pl. 14, fig. 1–7; text fig. 1–3. Santonian, France. (Published May 30, 1954).

TOURNAYELLIDAE fam. nov. Dain, 1953, *teste:* Malakhova, 251, p. 54.

TOURNAYELLA gen. nov. Dain, 1953, *teste:* Malakhova, 251, p. 54. No further information available to compiler.

*Triticites nakatsugawensis* Morikawa, **476,** p. 117, pl. 10, fig. 1–4,8,10,11–16,18,19. Upper Carboniferous, Japan.

—— —— —— var. *hemmii* Morikawa, **476,** p. 117, pl. 10, fig. 6,7,9. Upper Carboniferous, Japan.

—— *uemurai* Morikawa, **476,** p. 120, pl. 10, fig. 22–29. Upper Carboniferous, Japan.

*Tritubulogenerina dertonensis* Gianotti, **455,** p. 271, pl. 12, fig. 7. Tortonian, Italy.

*Trochammina ashiyaensis* Murata, **478,** p. 6, pl. 1, fig. 6. Oligocene, Japan.

SUPPLEMENT: NOMENCLATURA APERTA 1953

*Anomalina* sp. Phleger, Parker and Peirson, **486,** p. 48, pl. 10, fig. 26–28. Recent, North Atlantic.

*Bigenerina* sp. Gianotti, **455,** p. 217, pl. 10, fig. 4. Tortonian, Italy.

*Bolivina* sp. Gianotti, **455,** p. 270, pl. 12, fig. 13. Tortonian, Italy.

—— sp. 1 Phleger, Parker and Peirson, **486,** pl. 7, fig. 27,28. Recent, North Atlantic.

—— sp. 2 Phleger, Parker and Peirson, **486,** p. 37, pl. 7, fig. 29. Recent, North Atlantic.

*Buliminella* sp. Phleger, Parker and Peirson, **486,** p. 32, pl. 6, fig. 18. Recent, North Atlantic.

*Cassidulina* sp. 1 Phleger, Parker and Peirson, 486, p. 45, pl. 10, fig. 5. Recent, North Atlantic.

—— sp. Phleger, Parker and Peirson, **486,** p. 45, pl. 10, fig. 8,9. Recent, North Atlantic

*Chrysalogonium* sp. indet. Beckmann, **443,** p. 353, pl. 19, fig. 16. Lower Oligocene, Barbados.

*Cibicides* sp. Gianotti, **455,** p. 288, pl. 17, fig. 7. Tortonian, Italy.

—— sp. Phleger, Parker and Peirson, **486,** p. 50, pl. 11, fig. 18,22. Recent, North Atlantic.

*Cristellaria* sp. indet. Beckmann, **443,** p. 349, pl. 18, fig. 18. Eocene-Oligocene, Barbados.

*Discorbis* sp. 2. Gianotti, **455,** p. 276, pl. 17, fig. 16. Tortonian, Italy.

—— sp. Tavares Rocha and Martins Pereira, **510,** p. 140, pl. 1, fig. 4. Pliocene, Portugal.

*Dorothia* sp. indet. Beckmann, **443,** p. 342, pl. 17, fig. 13. Upper Eocene, Barbados.

*Ehrenbergina* sp. Gianotti, **455,** p. 282, pl. 17, fig. 4. Tortonian, Italy.

*Ellipsoglandulina* sp. indet. Beckmann, **443,** p. 380, pl. 23, fig. 16,17. Eocene-Oligocene, Barbados.

*Globigerina* sp. 1 Phleger, Parker and Peirson, **486,** p. 14, pl. 1, fig. 22,23. Recent, North Atlantic.

—— sp. 2 Phleger, Parker and Peirson, **486,** p. 14, pl. 1, fig. 26,27. Recent, North Atlantic.

*Globigerinoides* sp. Napoli Alliata, **479,** p. 105, text fig. B, No. 3. Miocene, Sicily.

*Globorotalia* sp. 1 Phleger, Parker and Peirson, **486,** p. 23, pl. 4, fig. 19–21. Recent, North Atlantic.

—— sp. 2 Phleger, Parker and Peirson, **486,** p. 23, pl. 4, fig. 15,16. Recent, North Atlantic.

*Goëssella* sp. indet. Beckmann, **443,** p. 343, pl. 17, fig. 20; text fig. 6. Upper Eocene, Barbados.

*Lenticulina* sp. Ruzicka and Benes, **495,** p. 36, text fig. 6. Tortonian, Czechoslovaquia.

*Loxostomum* sp. Gianotti, **455,** p. 273, pl. 12, fig. 11. Tortonian, Italy.

*Marginulina* sp. Ruzicka and Benes, **495,** p. 37, text fig. 8. Tortonian, Czechoslovaquia.

*Nodosaria* sp. Ruscelli, **494,** p. 131, pl. 5, fig. 12. Helvetian, Italy.

*Nodosarella* sp. indet. Beckmann, **443,** p. 377, pl 22, fig. 32. Oligocene, Barbados.

*Nonionella* sp. Gianotti, **455,** p. 255, pl. 12, fig. 4. Tortonian, Italy.

—— sp. Phleger, Parker and Peirson, **486,** p. 31, pl. 6, fig. 13,14. Recent, North Atlantic.

*Planulina* sp. Frenguelli, **453,** p. 46, fig. A. Post-Glacial, Argentina.

*Pseudoclavulina* sp. indet. Beckmann, **443,** p. 341, pl. 17, fig. 10. Oligocene, Barbados.

*Pullenia* sp. Phleger, Parker and Peirson, **486,** p. 48, pl. 10, fig. 22. Recent, North Atlantic.

*Rectouvigerina* sp. Phleger, Parker and Peirson, **486,** p. 38, pl. 8, fig. 8. Recent, North Atlantic.

*Siphogenerina* sp. indet. Beckmann, **443,** p. 369, pl. 21, fig. 22. Oligocene, Barbados.

*Spiroloculina* sp. Phleger, Parker and Peirson, **486,** p. 23, pl. 5, fig. 15,16. Recent, North Atlantic.

*Stilostomella ?* sp. indet. Beckmann, **443,** p. 372, pl. 21, fig. 41. Oligocene, Barbados.

*Textularia* sp. Gianotti, **455,** p. 217, pl. 10, fig. 1. Tortonian, Italy.

*Tretomphalus* sp. Gianotti, **455,** p. 279, pl. 16, fig. 9. Tortonian, Italy.

*Uvigerina* sp. 1 Phleger, Parker and Peirson, **486,** p. 38, pl. 8, fig. 6. Recent, North Atlantic.

—— sp. 2 Phleger, Parker and Peirson, **486,** p. 38, pl. 8, fig. 7. Recent, North Atlantic.

*Vaginulina* sp. indet. Beckmann, **443,** p. 354, pl. 19, fig. 22. Oligocene, Barbados.

*Verneuilina* sp. 1 Gianotti, **455,** p. 218, pl. 10, fig. 7. Tortonian, Italy.

—— sp. 2 Gianotti, **455,** p. 218, pl. 10, fig. 8. Tortonian, Italy.

*Virgulina* sp. indet. Beckmann, **443,** p. 367, pl. 21, fig. 14,15. Upper Eocene, Barbados.

—— sp. Phleger, Parker and Peirson, **486,** p. 35, pl. 7, fig. 9,10. Recent, North Atlantic.

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# PALEONTOLOGICAL NOTES

## GEOGRAPHIC LOCATIONS AND STRATIGRAPHIC HORIZON OF PENNSYLVANIAN FOSSIL FOOTPRINTS DISCOVERED IN OSAGE COUNTY, KANSAS BY B. F. MUDGE IN 1873

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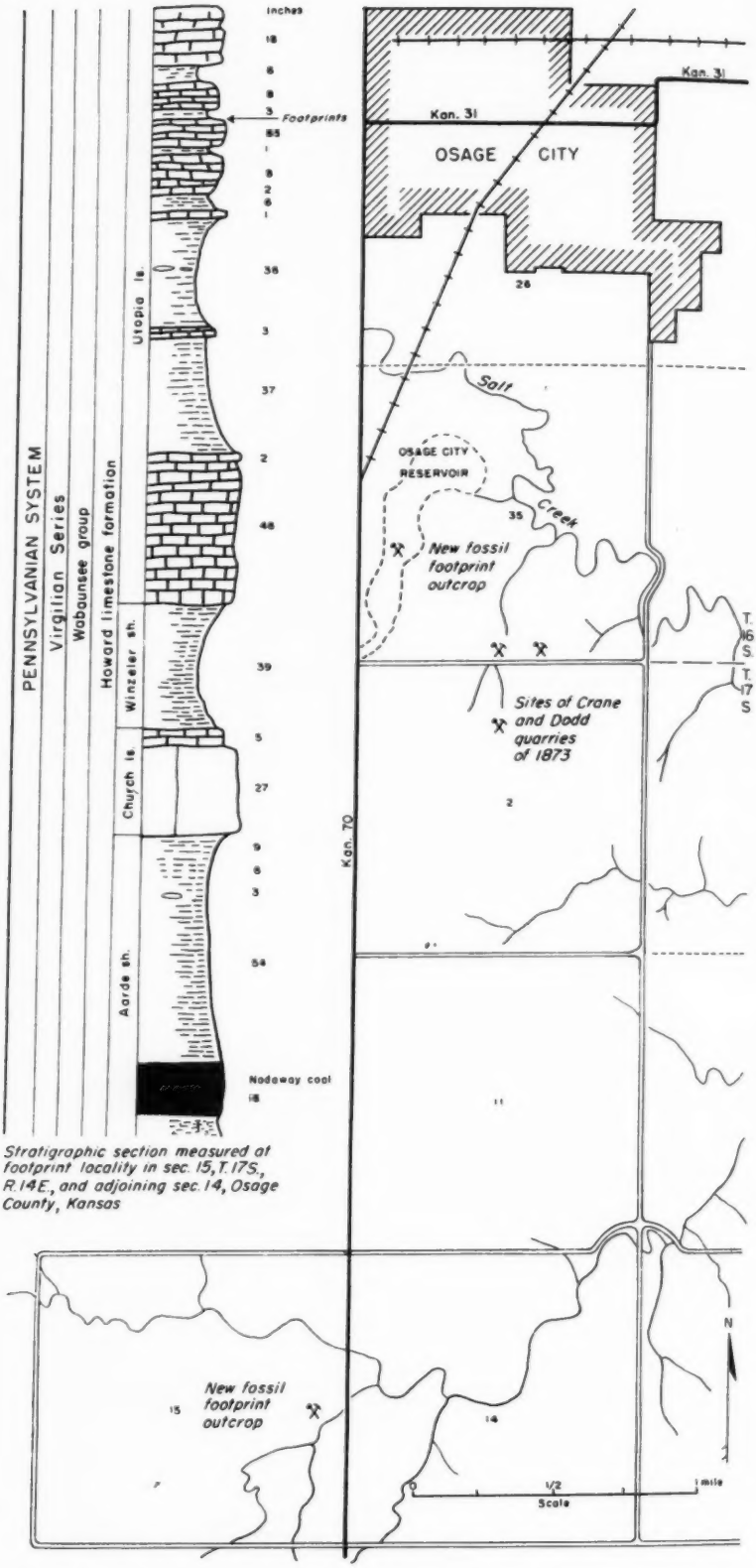
The relatively recent paper by Donald Baird (1952) concerning the revision of Pennsylvanian and Permian footprints, *Limnopus*, *Allopus*, and *Baropus* in this Journal focussed attention again to the fact that neither the exact geographic location nor the geologic horizon of the Osage County, Kansas, Pennsylvanian footprint strata are known. The purpose of this paper is to put on record (1) the now-known geographic locations of the Crane and Dodd quarries from which Mudge collected his specimens in 1873, (2) the stratigraphic horizon of the footprint-bearing strata, and (3) two new localities from which similar footprint impressions were obtained in 1954.

### HISTORICAL BACKGROUND

The fossil amphibian footprints were first discovered by Professor B. F. Mudge in 1873 on a sidewalk flagstone on Kansas Avenue in Topeka, Kansas. Mudge immediately traced the flagstone to the Crane and Dodd quarries at Osage (City) where he collected at least 30 large slabs which he had sent to Manhattan, Kansas, his home. Subsequently some of the slabs were sent to the University of Kansas and most of them to Yale University. Later, a slab from a sidewalk at Burlington, Kansas, found its way to the University of Missouri (Branson & Mehl, 1932, p. 388–391). Mudge (1874, p. 7–9; 1896 reprint p. 71–74) described his find without naming the fossils, believing that the footprints were those of at least four distinct species of reptiles, rather than of amphibians. As was characteristic of Mudge, most of his collections were sent to Professor O. C. Marsh of Yale University for further study, who Mudge stated "will then proceed to assign their true paleontological character and name them" (Mudge, 1874; 1896 reprint p. 74). Twenty years later Marsh (1894) published the results of his studies of the fossil footprints as an appendix in the American Journal of Science. In 1932, E. B. Branson & M. G. Mehl (p. 388–391) described some fossil footprints found in a sidewalk flagstone obtained at Burlington, Kansas, some 40 miles south of Osage City. Since this slab of flagstone, used as a sidewalk, was not *in situ* like the one originally discovered by Mudge in Topeka, no definite location as to its original source could be given by Branson & Mehl, who merely stated that it was "taken from a quarry near Osage City, Kansas" (Branson & Mehl, 1932, p. 388). Donald Baird (1952) likewise was unable to pin-point the locality or localities from which Mudge obtained his collection of slabs although he endeavored to ascertain the locations of the Crane and Dodd quarries by writing to me, knowing that I had previously mapped the Nodaway coal in Osage County (Schoewe, 1946). At the time of his inquiry (1951) the locations of the Crane and Dodd quarries were unknown to me.

### LOCATIONS OF CRANE AND DODD QUARRIES

The Crane and Dodd flagstone quarries of 1873, of which there were three, were located almost 2 miles south of the center of Osage City. Two of the quarries were in the SE¼ sec. 35, T. 16 S., R. 14 E., whereas the third was in the NE¼ sec. 2, T. 17 S., R. 14 E. (Text-fig. 1). The southernmost quarry, which was also the last one operated, was in sec. 2 about two-tenths of a mile due south of the NW cor. of the NE¼ of the section. Currently the quarry site is in timber traversed by a small intermittent stream and completely filled in with soil and debris so that except for slight irregularities and an occasional small flagstone lying about all traces of this quarry are gone. The other two quarries were close to the south line in the SE¼ sec. 35. One quarry was in the south-




TEXT-FIG. *1*—Map and stratigraphic section of Pennsylvanian fossil amphibian footprint localities and strata south of Osage City, Osage County, Kansas.

west corner of the quarter-section, whereas the other was two-tenths of a mile farther east. All evidence of the quarry in the southwest corner of the quarter-section is gone. The easternmost quarry is noticeable only because of the dump heap and the presence of an occasional small slab of the flagstone. No rocks in place are visible at any of the quarries. The Crane and Dodd quarries of 1873 were relocated by the help of Mr. Denny Whalen, an old time resident of Osage City, who as a young man worked for Crane and Dodd. Contact with Mr. Whalen was made through the register of deeds of Osage County at Lyndon and the newspaper editor of the Osage City Journal-Free Press. Mr. Whalen guided and accompanied me to the long abandoned quarries.

### THE STRATIGRAPHIC HORIZON

When Mudge discovered the fossil footprint-bearing slabs, very little was known concerning the details of the stratigraphy of the area. Mudge had to be content to say: "The deposit is just above the middle of the coal measures, and about a dozen feet above the coal seam worked at Carbondale and Osage" (Mudge, 1874; 1896 reprint p. 71). It was not until 1893 that geographic names were applied to rock formations in Kansas (Haworth, Kirk, & Piatt, 1894; Adams, Girty, & White, 1903, p. 23–27), and for a number of years afterward miscorrelations were not uncommon. Marsh (1894), erroneously cited by Branson & Mehl (1932, p. 388) as assigning the fossil-bearing strata to the Osage limestone, entirely ignored naming or locating the strata from which the fossil vertebrates were obtained. Haworth (1895, p. 462; 1895a, p. 278–279) refers the fossil-bearing strata to the Burlingame shale, which overlies a coal considered by him to be the equivalent of the coal mined at Burlingame and Osage City and which marked the top of his Osage City shale. Between the two shales was a thin limestone unit which Haworth, however, did not name but which was named the Osage limestone by Hall (Haworth et al., 1896, p. 104). The coal Haworth named was the Osage coal. Haworth was in error in believing that his Osage coal (Elmo) was the equivalent of the coal mined at Osage City (Nodaway). The coal mined at Osage City and above which Mudge obtained his collection of vertebrate fossils was correctly correlated with Haworth's Topeka coal seam (Nodaway) by St. John (1883) in 1881, as corroborated by Beede in 1898 (p. 28–29). Haworth apparently overlooked or had forgotten this correlation. Haworth's Topeka coal seam, formerly mined at Topeka, lay approximately 100 feet stratigraphically below his Osage coal which was formerly mined several miles west of Topeka. In referring to the Topeka coal, Haworth (1895b, p. 304) stated that it was "not the geologic equivalent of any other coal known in the state." In 1897 Adams (Haworth, E., & Crane, W. R., 1898, p. 65–67) named the Osage limestone the Howard limestone. Branson & Mehl (1932, p. 388) referred the limestone to the Scranton shale "as in keeping with present-day usage." The current classification of the Howard limestone formation with its five members dates back to 1932 (Moore, 1936, p. 204–209). It should be noted (1) that all references to the geologic horizon at which the flagstones occur are based upon Mudge's general and indefinite statement that the "deposit is just above the middle of the coal measures, and about a dozen feet above the coal seam worked at Carbondale and Osage," and (2) none of the describers of the fossil footprints, with the exception of Mudge, had actually seen the flagstones in place and consequently could not be certain as to the exact stratigraphic horizon at which the flagstones occurred. On the basis of a letter dated April 6, 1951, written by Schoewe to Baird (1952, p. 834), Baird in redescribing the footprints assigned the geologic horizon at which the fossils occur as "Upper Pennsylvanian, Virgil series, Wabaunsee group, flaggy sandstones [actually limestones] about 12 feet above Nodaway coal. Probably Utopia limestone member of Howard limestone formation" (Baird, 1952, p. 835–836).

Lithologically the fossil-bearing strata are fine-grained, thin bedded limestones. Mudge called them flaggy sandstones. Marsh described them as calcareous shales, Haworth as shaly sandstones. Branson & Mehl did not name the rock but referred the fossiliferous strata to the Scranton shale, and Baird lists them as flaggy sandstones.

TABLE 1.—MEASURED SECTION AT THE AMPHIBIAN FOOTPRINT LOCALITY IN SEC. 15, T. 17 S., R. 14 E., AND ADJOINING SEC. 14, OSAGE COUNTY, KANSAS

Pennsylvanian—Virgilian series, Wabaunsee group, Howard limestone formation

| | Inches |
|---|---|
| Utopia limestone member | |
| 23. Limestone, dark gray, crystalline, irregularly bedded, fossiliferous especially pelecypods and gastropods, upper foot abundant fusulinids | 18–58 |
| 22. Shale, gray | 6– 7 |
| 21. Limestone, silty, slabby, smooth | 8–12 |
| 20. Shale | 3 |
| 19. Limestone, brownish gray, slabby, fine-textured, amphibian footprint impressions | 8.5 |
| 18. Shale, limey | 1 |
| 17. Limestone, slabby | 8 |
| 16. Limestone, thin-bedded | 2 |
| 15. Shale, light gray | 6 |
| 14. Limestone, dark gray, dense | 1 |
| 13. Shale, dark gray to black, limey, fissile, ostracodes abundant, limestone nodules in middle | 34–36 |
| 12. Limestone | 3 |
| 11. Shale, clay, brown | 37 |
| 10. Limestone, smooth, dense, pelecypods abundant | 1– 2 |
| 9. Limestone, gray, thin irregular beds, shelly, coconoid, pelecypods and gastropods abundant, weathers into large rectangular slabs—base of Utopia | 36–46 |
| Winzler shale (section 14) | |
| 8. Shale, bluish, sandy limestone nodules | 39 |
| Church limestone (section 14) | |
| 7. Limestone, thin-bedded | 5 |
| 6. Limestone, massive bed, dense bluish gray weathers brownish | 27 |
| Aarde shale (section 14) | |
| 5. Shale, gray | 9 |
| 4. Shale, black | 6 |
| 3. Shale, gray, limestone nodules 3 inches below top | 56 |
| 2. Coal—Nodaway | 16 |
| 1. Shale, sandy | |

After visiting the Crane and Dodd quarry sites and finding there several small broken flagstone slabs lying about the debris, and recognizing the rock as the same as that outcropping along a small stream, 2.5 miles south and half a mile west, the writer searched for fossil footprints at the outcrop on September 6, 1954, and found *in situ* a slab containing well preserved footprint impressions similar to those described and illustrated by Baird. The tracks found occur in the upper part of the Utopia limestone, 12 feet above its base and 24 feet above the Nodaway coal (Text-fig. 1). There is, therefore, no longer any doubt as to the stratigraphic horizon at which Mudge secured his specimens. The description of the fossil-bearing strata should now read "Upper Pennsylvanian, Virgil series, Wabaunsee group, flaggy limestones about 24 feet above Nodaway coal. Uppermost beds of Utopia limestone member of Howard limestone formation." A detailed stratigraphic section measured at the new locality is herewith presented and graphically shown in Text-fig. 1. An almost similar Howard limestone formation sequence of strata occurs north of Valley Falls in Jefferson County in the NW cor. NE¼ SW¼ sec. 8, T. 8 S., R. 18 E., about 60 miles north of the Osage quarry sites. Thus far no amphibian tracks have been found in the limited outcrop at this locality.

### NEW FOSSIL FOOTPRINT LOCALITIES

Fossil amphibian footprints were collected by me at two new outcrop localities. The better locality is approximately in the NE cor. SE¼ sec. 15, T. 17 S., R. 14 E., on the west side of Kansas highway 70 about 2.5

miles south and one-half mile west of the Crane and Dodd quarry sites or about 4.25 miles south of Kansas highway 31 leading into Osage City from the west. The outcrop forms the bed and banks of a small intermittent stream tributary to Salt Creek. A second new fossil footprint locality was found a short distance west of the center of the SW¼ sec. 35, T. 16 S., R. 17 E., about 0.35 mile west and a similar distance north of the Crane and Dodd quarry in the SW cor. SE¼ sec. 35, T. 16 S., R. 17 E. The flagstone occurs in the creek bed of a small stream bisecting the Osage City golf course. Normally the site is under water, being part of the Osage City municipal water reservoir. Due to drought conditions this portion of the reservoir was completely dry in September, 1954, exposing portions of the same flagstone cropping out in section 15 almost three miles farther south. Whether the footprints in this locality occur in exactly the same bed as those obtained farther to the south could not be ascertained in the field. There is no question, however, that the horizon is the upper part of the Utopia limestone member.

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# UPWELLING AND ASSOCIATED MARINE LIFE ALONG PACIFIC BAJA CALIFORNIA, MEXICO*


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## INTRODUCTION

Recent studies of the marine benthic organisms inhabiting the northwestern coast of Baja California, Mexico, indicate the presence of discontinuous intertidal and inner neritic distribution for certain forms. This unusual distributional pattern requires an oceanographic explanation, apparently explained by local upwelling of cold water.

This investigation is concerned primarily with the influence of upwelling upon the distribution of the marine invertebrates, especially the mollusks, and the application of this phenomenon to paleoecological interpretations. It seems advisable to place the preliminary findings on record. An analysis of the importance of upwelling on the climate, physiography, and non-marine biotas of adjacent land areas is beyond the scope of this paper. The reader is referred to Brongersma-Sanders (1948) for a critical re-

* Contribution from the Museum of Paleontology, University of California, Berkeley.

view of the known effects of upwelling and to Sverdrup et al. (1946) for an explanation of this phenomenon.

Many species of stenothermal cold-water organisms frequent intertidal or shallow water in high latitudes and occur in progressively deeper water as they range toward the equator. The southern range limits of many of the northeastern Pacific forms are not known, due to a paucity of bathymetric records; however, the appearance of cold-water species in the intertidal zone along parts of the coast of Baja California presents an interesting problem to students of zoogeography and ecology.

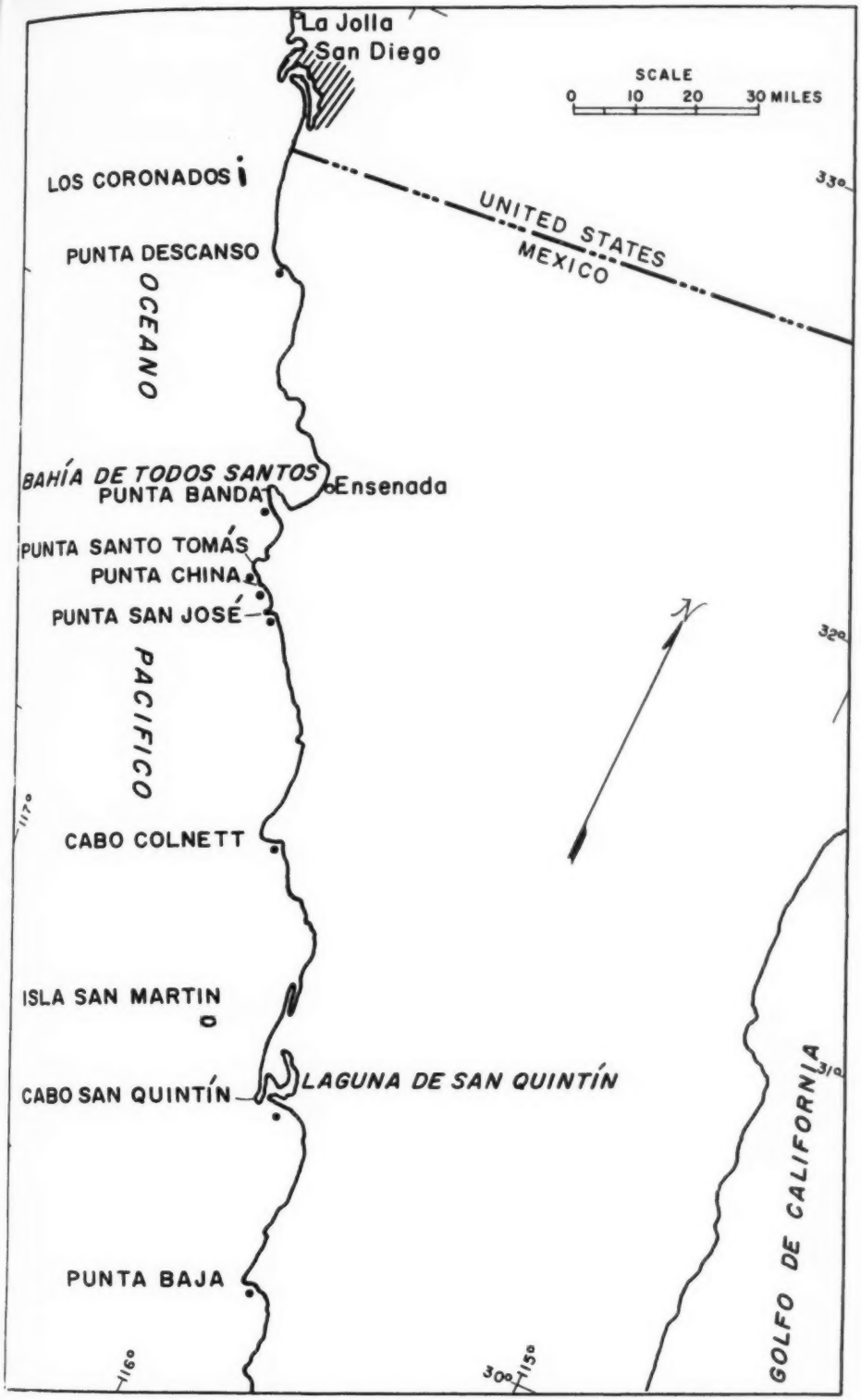
## UPWELLING ALONG PACIFIC BAJA CALIFORNIA

A series of surface temperature observations and bathythermograms undertaken by Dawson (1951) demonstrated the occurrence of upwelling along virtually the entire Pacific coast of Baja California. Dawson's hydrographical and biological investigations indicate the presence of four regions which can be identified by differences in geographical or seasonal continuity of upwelling. North of latitude 27° N., upwelling appears to be seasonally continuous in local areas, some of which are rather extensive. The northernmost region, Punta Descanso to Bahía de San Quintín, is the area pertinent to this study (Text-fig. 1). Here much of the coastline trends in a north to northwest direction, but is broken by several large headlands, south of which the coastline is first east to west, then northwest to southeast. In this region, the intense along-shore upwelling occurs when the prevailing winds blow the water surface upward, to be replaced rapidly by water drawn from a few meters below the surface (personal communication, C. L. Hubbs, Aug., 1954). Inasmuch as the winds are predominantly from the northwest to the southeast, upwelling is intensified south of the headlands. Hydrographical and biological evidence support this tenet. The stretches of shore between the prominent headlands were found to have greater temperature variations, depending largely upon the degree of stagnation or movement of upwelled water along the shore. As would be expected, upwelling has little influence in areas of protected or semi-protected shoal water such as Laguna de San Quintín and Bahía de Todos Santos. In summary, this region is characterized by geographically discontinuous areas of upwelling in which the centers of intensity are located on the south sides of the more prominent headlands (*cf.* Dawson, 1951).

*Previous work.*—Although upwelling off western North America has been known for some time, with intensification along certain areas of the Baja California coast (McEwen, 1916), the role of this phenomenon as a factor in the distribution of marine organisms has received little attention until recently. Studies on the distribution of marine floras and faunas along the Pacific coast of Baja California by Dawson (1946–1952) on algae, by Hubbs (1948) on fishes, and by Emerson (1952) on invertebrates show a close correlation with the presence or absence of upwelling. Within the areas of upwelling many species characteristic of more northern waters occur far south of their expected latitudinal range, producing a discontinuous intertidal distribution for these organisms.

*Neontological evidence.*—Although the writer has not had an opportunity to make comprehensive collections from the upwelling "cold-spots," an hour's collecting at a low tide produced the following stenothermal cold-water organisms from the intertidal zone on the south side of Punta Santo Tomas:

1. *Balanophyllia elegans* Verrill, a stony coral; recorded range: British Columbia southward to Point Conception and through the Channel Isls., California, shore to 160 fathoms (Durham & Barnard, 1952); identification by J. Wyatt Durham.
2. *Acmaea mitra* Eschscholtz, a limpet; recorded range: Pribilof Isls., Alaska, to San Diego, California, infra-tidal in southern extent of range (Keen, 1937).
3. *Hapalogaster cavicauda* Stimpson, a crab; recorded range: Cape Mendocino, California, to Monterey and through the Channel Isls., California (Ricketts & Calvin, 1952; Johnson & Snook, 1935); identification by John S. Garth.
4. *Idothea stenops* (Benedict), an isopod; recorded range: Coos Bay, Oregon, to Monterey, California (Menzies, 1950); identification by Robert J. Menzies.




TEXT-FIG. *1*—Chart of the coastline from La Jolla, California, to the vicinity of Punta Baja, Baja California. Areas of local upwelling, which are indicated by solid circles, occur south of Punta Descanso, Punta Banda, Punta Santo Tomás, Punta China, Punta San José, Cabo Colnett, Cabo San Quintín, and Punta Baja (data after Dawson, 1951, in part).

According to Dr. E. Yale Dawson (personal communication, August, 1954) the algal flora of Punta Santo Tomás contains a number of northern species, including: *Laminaria farlowii* Setchell, *Zanardinula lanceolata* (Harvey) J. De Toni, and *Gigartina californica* J. G. Agardh. These species occur intertidally in central California.

A number of other cold-water organisms is recorded from the intertidal zone of several Baja California localities which are now known to be areas of upwelling. Burch (1946) reported *Placiforella velata* Carpenter (a chiton which is recorded in infratidal waters south of Monterey, California) and *Acmaea mitra*, together with other northern species, on the south side of Punta Banda. At this locality, the writer found the water temperature to be 7° to 10°F. lower than that on the north side of the peninsula. Several northern species of pholad clams were collected by Fitch (1953) from localities along the Baja California coast. Hubbs (1948) recorded from south of the international border the intertidal occurrence of the abalone *Haliotis rufescens* Swainson and the sea urchin *Strongylocentrotus franciscanus* A. Agassiz, which occur near San Diego, California, in infratidal water or are rarely exposed by the extremely low, spring tides.

In the areas concerned here, upwelling appears to be at a maximum during the spring and summer months, the critical reproductive period for many of the invertebrates. It seems, therefore, that the cold-water invertebrates are able to maintain local populations within the areas of upwelling and do not require continual larval replenishment from off-shore sources or from more northerly located populations.

## APPLICATION TO PALEOECOLOGY

At present, the permanence of the upwelling areas in time must be considered a matter for conjecture owing primarily to the multiplicity of the interacting factors upon which the phenomenon is dependent. The matter of temporal permanency is of prime importance for paleoecological considerations. Brongersma-Sanders (1948) interprets certain evidence from the fossil record as indicating the probable existence of upwelling in past geological ages. The paleontologist would possess a valuable new adjunct for ecological interpretations if the antiquity of upwelling could be unequivocally demonstrated and if it were possible to recognize with a reasonable degree of certainty the effects of this phenomenon in the fossil record. Its application to paleoecological interpretation would necessitate a re-examination of many of our present assumptions. For example, in some instances, upwelling rather than climatic isothermal shift may be the explanation for apparent critical changes in temperature conditions which are now recognized in some of the faunas of the West American Pliocene-Pleistocene sequence.

*Paleontological evidence.*—At Punta China (see Text-fig. 1) a large series of invertebrates were collected from a highly fossiliferous marine Pleistocene terrace deposit which occurs in the vicinity of this upwelling site. Field evidence based on geologic and faunistic data indicates the probable existence of the headland during the deposition of this terrace and a coastal topography essentially the same as today. A study of these fossils was undertaken to determine if the effects of upwelling could be detected in the composition of the faunule. The preliminary results of this investigation are not conclusive. Although stenothermal cold-water organisms, including the coral *Balanophyllia elegans* and the limpet *Acmaea mitra*, occur in this fossil tide-pool and rock-cliff assemblage, there are also present some northern species which have not been found living in the upwelling areas (e.g. *Tegula brunnea* Philippi and *Cryptochiton stelleri* Middendorff[1]). On the basis of the available data, it is difficult to determine if the cold-water elements in the fossil faunule reflect the influence of upwelling, isothermal shift, or possibly a combination of these, together with other factors. Valentine (1955) has interpreted the presence of cold water, exposed coast elements in the molluscan faunas of some Pleistocene terrace deposits of Southern California and Baja California to suggest the presence, at the time these faunas lived, of local upwelling with lower temper-

[1] It is interesting to note that valves of this chiton are commonly found in the kitchen middens which occur in the region, but the species has not been reported living along this coast. Drs. S. Stillman Berry and Carl L. Hubbs have in preparation a manuscript on the distribution of this species in the midden deposits of the Pacific coast of Baja California.

atures than exist in the present upwelling areas along northern Baja California.

It is evident that additional neontological and paleontological data must be obtained before more definite conclusions can be reached concerning the significance in this region of upwelling as a paleoecological factor. Carl L. Hubbs of the Scripps Institution of Oceanography is presently conducting an exhaustive thermal and zoological survey of the inshore area of northwestern Baja California. The results of this investigation, supplemented by oxygen[18] and carbon[10] studies, promise to yield much additional information on the relation of upwelling to temperature and animal distribution.

## CONCLUSION

The possibility of the existence of upwelling in past geological ages and its potential role as an ecological agent should not be neglected by the paleontologist. A better understanding of the influence of this phenomenon on the distribution of living marine organisms, particularly benthic forms, holds promise for paleoecological applications. Moreover, the intertidal occurrence of frigophilic (cold-limited) plants and animals in the upwelling areas of the Baja California coast serves to demonstrate the advisability of utilizing thermophilic (warm-limited) species as indices for the interpretation of former climatic conditions of fossil faunal assemblages.

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# AN *ENGONOCERAS* FROM CENTRAL OREGON

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The discovery of a species of *Engonoceras* in Cretaceous beds in central Oregon represents the only known occurrence of that genus from the Pacific Coast region of North America and the second report for the vast Indio-Pacific Cretaceous province.

This new species was found by Loren B. McIntyre, a student at Oregon State College, while studying a Cretaceous section within the Mitchell quadrangle, Wheeler County, Oregon. He has generously granted the author the privilege of describing this unique specimen.

The author is grateful for the laboratory and library facilities afforded him by Stanford University and especially for the interest Dr. Siemon W. Muller has taken in this study. Dr. H. B. Stenzel granted him the privilege of examining the large collections of engonoceratids in the Texas Bureau of Economic Geology at Austin.

This species is named for Dr. William D. Wilkinson in recognition of his and his students' contributions to the knowledge of the field relationships of the Cretaceous of central Oregon. The genus *Engonoceras* is the type of the family Engonoceratidae Hyatt (1900), which includes a number of more or less related genera, collectively known as "pseudoceratites." Some of these genera are of questionable taxonomic validity. The following résumé of the historical development of our knowledge of this group will serve to place the genus *Engonoceras* in proper perspective among the related genera of the family.

Neumayr & Uhlig (1881, p. 140–141), introduced the name *Engonoceras* in a synoptic key in which their new genus was characterized by three or more lateral ceratitic lobes. They listed as examples, *Engonoceras pierdenale* (Buch), *E.* cf. *E. vibrayeanum* (d'Orbigny), and *E. vibrayeanum* (d'Orbigny).

The species *E. pierdenale* was subsequently designated the type of the genus *Engonoceras*, and *E. vibrayeanum* with entire saddles and lobes became the type species of *Neolobites*, which was established by Fischer in 1882. In 1898 Boehm emended the scope of the genus *Engonoceras* and published detailed descriptions and drawings of most species which were known at that time. Slightly ornate forms with three adventitious lobes and with smooth or almost smooth lateral saddles were placed by Boehm into a new genus *Knemiceras* with *Ammonites syriacum* Buch as the type. Another genus, *Protengonoceras* with the type species *Protengonoceras gabbi* (Boehm) = *Ammonites pedernalis* Buch of Gabb, was added to this group by Hyatt when he proposed for all these "pseudoceratites" the family taxon Engonoceratidae.

In 1903 Hyatt in his monumental monograph on the "Pseudoceratites" added the genus *Metengonoceras* (type species *Metengonoceras inscriptum* Hyatt). Further "fragmentation" of the group was effected by Spath, who in 1921 proposed the genus *Hypengonoceras* (type species *Placenticeras worthi* Kossmat) and again in 1924 proposed the genera *Epengonoceras* (type species *Sphenodiscus dumbelei* Cragin) and *Parengonoceras* (type species *Amaltheus ebrayi* deLoriol). In 1931 Spath transferred the genus *Hypengonoceras* to the family Placenticeratidae and in the same paper, following Pervinquière, questioned the generic differences between *Engonoceras* and *Protengonoceras* as well as the validity of *Epengonoceras*. The crenulated saddles of the type of *Parengonoceras* differ markedly from the generally entire saddles of *Engonoceras* and therefore that group probably should have generic rank. The generic rank of *Metengonoceras* is not as easily justified.

There are differences of opinion regarding the ancestry of the genus *Engonoceras* as reviewed by Spath (1931, p. 340–342). He regards this smooth form as a derivative of the ornamented genus *Knemiceras* Boehm. However, since both genera have been reported from the Aptian of South America such a conclusion may be subject to revision.

About a score of species referred to *Engonoceras*, or to one of the above-mentioned closely related groups of species, have been described from the Mexican geosyncline. In Texas they range from the Trinity (late Aptian) to the Eagle Ford (early Cenomanian). The larger number occur in the Fredricksburg and Washita groups (middle and late Albian). The two known species from England are late Albian. In Europe, the Near East, and northern Africa the engonoceratids may occur as late as early Senonian.

The absence of *Engonoceras* and its close allies in the Indian Albian faunas was noted by Spath (1930, p. 65) and in the Indio-Pacific region by Diener (1925, p. 239). More recently Matsumoto (1954, table 21) listed *Engonoceras* aff. *E. stolleyi* Boehm in a late Albian or Cenomanian fauna from the Japanese Yatsushiro formation.

The larger number of species of *Knemiceras* occur in the Middle East and northern Africa. They are also known from Europe, South America and a few from North America. A possible representative has been reported from Borneo (Diener, *op. cit.* p. 239).

The abundance of species of engonoceratids in North America has led authors to suggest that the Mexican geosyncline was the center of distribution of these forms. However their absence or rarity outside that region may be due in part to an adaptation of these ammonites to a particular environment which did not prevail elsewhere while contemporaneous deposits were accumulating.

Scott (1940, p. 331) reported that in Texas *Engonoceras* occurred typically in arenaceous limestones developed in less than twenty fathoms of water.

The Oregon specimen was found within a two-foot lens of calcareous sandstone in a massive conglomerate. Such an occurrence would imply a shallow water environment for the new species. The meagre associated fauna includes:

*Trigonia*, sp. (imperfect mold)
*Anomia* (*?*), sp.
pelecypods (several minute forms)
*Dentalium*, sp.
*Natica* (*?*), sp.
gastropod (juvenile, possibly allied to *Tessolax*)
fossil wood

ENGONOCERATIDAE Hyatt 1900
ENGONOCERAS Neumayr & Uhlig 1881
Genotype: *Ammonites pierdenalis* von Buch

The spelling of this specific name was changed to "*pedernalis*," by Römer in 1852 to conform to the name of the Texas stream along which it was found. See Boehm (op. cit., footnote p. 153); he and many later authors accepted that unjustified change.

ENGONOCERAS WILKINSONI Packard, n. sp.
Text-fig. 1-A–1-C

This species is based upon an incompletely preserved single specimen. It consists of about one half of an outer whorl, including a small part of the slightly crushed body chamber and about one third of the penultimate whorl. Two short sections of the periphery of the non-septate portion show the nature of the ventral region of that whorl. The portion of the earlier whorl is well preserved and reveals important diagnostic features.

The conch is discoidal, compressed with flattened flanks that slope regularly from the umbilical shoulder to the narrow venter. The umbilicus is small, equaling in width about 8 percent of the estimated diameter of the specimen. The impressed zone of the outer whorl is about 15 millimeters deep. The umbilical walls are unornamented as are the well rounded shoulders of both whorls. The flanks are likewise smooth, except for fine growth lines well shown on the penultimate whorl and less clearly seen on the outer volution. The venter of the pentultimate whorl is thin, distinctly concave or grooved, at least to a whorl height of 19 millimeters, and is bordered by sharp edges. The periphery of the anterior portion of the outer whorl is narrow, flat and bordered by unornamented, sharply rounded shoulders. The change from the grooved to the flattened venter is probably gradual, but as a considerable part of the outer margin is missing, no transitional changes could be observed.

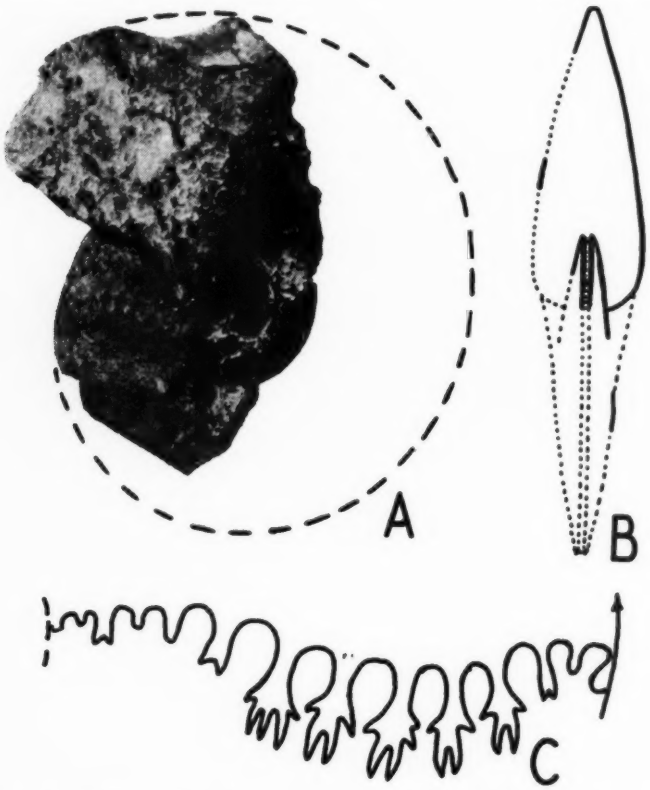
The line of sutural elements is concave toward the aperture from the venter to the auxiliaries where it becomes slightly concave in the opposite direction.

The varying number of adventitious and

auxillary lobes and saddles developed by the pesudoceratites present difficulties in the identification of the first lobe of a new species for which the ontogeny is unknown. Therefore, it seems desirable to state that for the purposes of this paper, the external saddle is considered as being divided by three adventitious lobes and therefore includes four adventitious saddles. Thus, the first lobe may or may not represent the true one when the ontogeny of the species becomes known.

As defined above the external saddle is divided by three adventitious lobes of which the first is shallow, the second narrow and bifid and the third much deeper and closely resembles that of the first lobe. The first two adventitious saddles are entire and similar in shape and size. The third is higher, broader and like the fourth has the general shape and size of the first true saddle. That one and the following two are broad, phylliform, entire and are all nearly of the same size. The stem of these and the last adventitious saddle are constricted in a unique manner by lateral inflections from the lobes. The one on the outer side is situated a little forward of its opposite on the other side of the stem. That arrangement allows greater depth of the inflection without severing the stem. The first and second auxiliary saddles are broad, but the remaining are small, low, and ill defined.

The shallow ventral lobe had the oblique lobules typical of the genus. The first adventitious lobe is shallow, entire and parallels the ventral margin. The second is slightly oblique, bipartate and reaches below the level of the ventral lobe. The next is wide, deep and terminates in two sharp divisions




TEXT-FIG. 1—*Engonoceras wilkinsoni* Packard, n. sp. The holotype, ×1, and an enlarged representation on the external suture.

and possesses a pair of unequal lateral inflections. The first and second lobes are the deepest of the entire series. Their bipartite terminations and lateral inflections are similar to those of the last adventitious lobe and also to the succeeding third lobe. The next lobe is the widest of the series and appears to be tridentate with the lateral inflections less well developed. The remaining auxiliaries are shallow and only two appear to be divided.

| | |
|---|---|
| Maximum diameter (estimated) | 71 mm. |
| Height of last whorl | 36.3 mm. |
| Width of last whorl | 11.3 mm. |
| Width of umbilicus | 5.7 mm. |
| Involution of last whorl | 15 mm. |
| Maximum height of preceding whorl | 17.3 mm. |
| Width of preceding whorl | 5.3 mm. |

*Occurrence.*—Oregon State Locality. In the SW¼, SE¼, NE¼, Sec. 29, T. 11 N., R. 22 E., Mitchell quadrangle, Wheeler County, Oregon. Probably late Albian in age. From a two-foot lens of hard calcareous sandstone within a massive conglomerate. Above an extensive body of fossiliferous shale with an Albian ammonite fauna and about 100 stratigraphic feet below the contact with the Clarno formation.

*Depository.*—Holotype deposited in Stanford Univ., Paleontological Type Coll.8321. Plastotypes at Oregon State College and California Academy of Sciences.

*Remarks.*—This new species of *Engonoceras* may be characterized by its small, compressed conch; flat and unornamented flanks; narrow and channeled venter, without bordering nodes up to whorl height of about 20 millimeters, and by a narrow but flattened venter on the body whorl. The suture with four adventitious saddles is followed by three well developed and several auxiliary saddles. The principal lobes are deep and possess unique lateral inflections that markedly restrict the stem of the saddles.

Due to the relatively poor state of preservation of the Oregon specimen no attempt is made to assign it to any of the allied groups, subgenera, of engonocerids. However, comparisons with the type species of those groups can be listed.

It has long been recognized that the early stages of at least some species of *Engonoceras* are unornamented and have sharp and often grooved venters. In later growth stages these same species develop broader venters and umbilical and ventral nodes and costae on the flanks. It is recognized that the new species from Oregon may represent an immature individual, yet its suture appears more highly specialized than that of most known species at a greater diameter.

The suture of *E. wilkinsoni* differs from *E.* (*Protengonoceras*) *gabbi* in its more sharply defined elements; from that of *E.* (*Metengonoceras*) *inscription* by its deeper and more digitate lobes and more elliptical principal saddles; from *E.* (*Epigonoceras*) *dumbelei* by its more phylliform saddles and deeper lobes; and from *E.* (*Parengonoceras*) *ebrayi* by its simple phylliform principal saddles and simpler and deeper lobes.

The suture of *E. pierdenalis*, the type species of *Engonoceras*, has the general form of that of *E. wilkinsoni*, but the adventitious lobes of the new species are deeper, the principal saddles more ovate, and the lobes are more digitate. Specimens referred to *E. pierdenalis* in the collection of the Texas Bureau of Economic Geology also differ in the presence of costae at diameters as small as 35 millimeters.

The Cenomanian species *E. thomasi* Pervinquiére has a smooth flank and a truncated venter, but the Oregon species has a sharper and more distinctly gooved venter and deeper and more clearly divided principal lobes.

The only previously known engonoceratid from the Indio-Pacific province was reported by Matsumoto (1954, table 21) as *E.* aff. *E. stolleyi* Boehm. That Japanese representative has not been described nor illustrated. However, Dr. Matsumoto has kindly informed the author (letter of March, 1955) that the two known specimens are crushed, small and "that further collection is necessary for lending clearer conclusion." The apparent differences between the specimen from Oregon and those found by Matsumoto indicate the presence of two distinct species within this province.

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## TORNOCERAS FROM THE DEVONIAN ONONDAGA LIMESTONE OF NEW YORK

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### INTRODUCTION

Comparatively few goniatites have been reported from the late Lower or early Middle Devonian (Onesquethaw stage) of North America. Miller (1938, p. 5) indicated known occurrences of specifically identified forms as follows:

Lower Nevada limestone, Nevada—
*Agoniatites? desideratus* (Walcott)
*A. nevadensis* Miller
Onondaga shale (lower Romney formation), Virginia and Maryland?—
*Tornoceras buttsi* Miller
Columbus limestone, Ohio—
*T. mithrax* Hall

An additional species "*Anarcestes* cf. *lateceptatus*" reported by Stauffer (1909, p. 168, 174) from the Columbus limestone was questioned by Miller (p. 5). Flower (1939, p. 432) considered it "highly suggestive of *Werneroceras plebiforme*" which is characteristic of the upper Union Springs shale immediately below the Cherry Valley limestone in New York. Neither Miller nor Flower saw the specimen so its identity is still in question. Each of the above species is known from only one or two specimens.

Additional "upper Onondaga" specimens from Maryland and Pennsylvania have been

identified as *Agoniatites vanuxemi* (Kindle, 1912, p. 37, 107; Prosser & Kindle, 1913, p. 321–323). These are poorly preserved and Miller (p. 5) considered their specific affinities to be uncertain.

Willard (1939, p. 159) listed "Goniatites undetermined" from the Selinsgrove and Needmore units of the Onondaga group in Pennsylvania and questionably from the older Esopus shale. "*Agoniatites expansus*" (=*vanuxemi*) was listed from the Onondaga in Maryland, but presumably this is drawn from earlier literature and Miller's remarks apply.

Butts (1940, p. 305) listed *Tornoceras buttsi* from the Onondaga shale (lower Romney) in Virginia. This is in reference to the specimen described by Miller which was collected originally by Butts (Miller, 1938, p. 148).

Woodward (1943, p. 296) reported abundant *Agoniatites vanuxemi* from the Needmore shale of West Virginia. He correlated this with the upper Onondaga limestone (New York), the Columbus limestone (Ohio) and the Onondaga shale member of the Romney formation (Virginia). The Needmore fauna (Woodward, 1943, p. 302) appears rich enough in Hamilton species to represent part of the lower Hamilton as well, and the abundant *A. vanuxemi* may mark the Cherry Valley horizon.

The West Virginia and Ohio goniatites and most of the undetermined ones from Pennsylvania and Maryland are younger than the Nedrow species herein described. The lower Romney form (*Tornoceras buttsi*) and the "undetermined" Esopus and Needmore specimens from Pennsylvania may be of equivalent or slightly greater age. The unidentified forms are interesting in showing the geographic and stratigraphic extent of the group as a whole.

In New York, Clarke (1901, p. 121; 1903, p. 535) reported *Agoniatites expansus* (= *vanuxemi*) from the uppermost Onondaga in the western part of the state. According to Miller (1938, p. 54) these are "probably specifically distinct from the typical form which occurs in the Cherry Valley limestone." However, the beds from which Clarke's specimens came are nearly if not exactly equivalent to the Cherry Valley limestone farther east (Oliver, 1954, p. 645–647), and the specimens might well be *A. vanuxemi*. Flower (1939, p. 432) would seem to agree with this interpretation. No other goniatites have previously been noted in the New York Onondaga.

ACKNOWLEDGMENTS

Thanks are due Dr. A. K. Miller of the State University of Iowa and Dr. J. W. Wells of Cornell University, both of whom read preliminary copies of the manuscript and made several comments and suggestions which have been adopted in the final draft. I am also indebted to Dr. G. Arthur Cooper of the United States National Museum for the loan of the holotype of *Tornoceras buttsi* Miller.

STRATIGRAPHY

The new material is from the Nedrow member of the Onondaga limestone in the Richfield Springs (15 minute) quadrangle of eastern New York. Oliver (1954) described the formation in the central part of the state. Further work in eastern New York has produced much new information which is in the process of study, but the general stratigraphic situation in the area under consideration is as indicated in the earlier paper (Oliver, 1954, pl. 1).

The general Onondaga sequence in the Richfield Springs quadrangle is as follows (ascending order):

Edgecliff member, 20 feet.
: The lower half is a fine-grained, medium-gray, thick-bedded limestone with a sparse rugose coral fauna. The upper half is a coarse, light-gray, massive limestone with abundant solitary rugose and tabulate corals in a crinoidal matrix.

Nedrow member, 10–12 feet.
: Thin bedded to shaly limestone with a platyceratid gastropod and brachiopod fauna; upper part (with goniatites) is more massive and grades to the succeeding member.

Moorehouse member, 70–80 feet.
: Fine-grained, dark-gray limestone with abundant black chert; brachiopods predominate, gyroconic nautiloids are characteristic.

Seneca member, 6 feet.
: Medium-grained, medium-light-gray, fairly massive limestone; brachiopods common.

The Nedrow member is well down in the formation and the new goniatite specimens represent the earliest yet described from New York.

SYSTEMATIC DESCRIPTION

*Tornoceras* cf. *T. buttsi* Miller
Text-fig. 1a,b

This description is based on a single specimen, an internal mold that is fairly well preserved. The specimen is eroded on one side but appears to be virtually complete on the other.

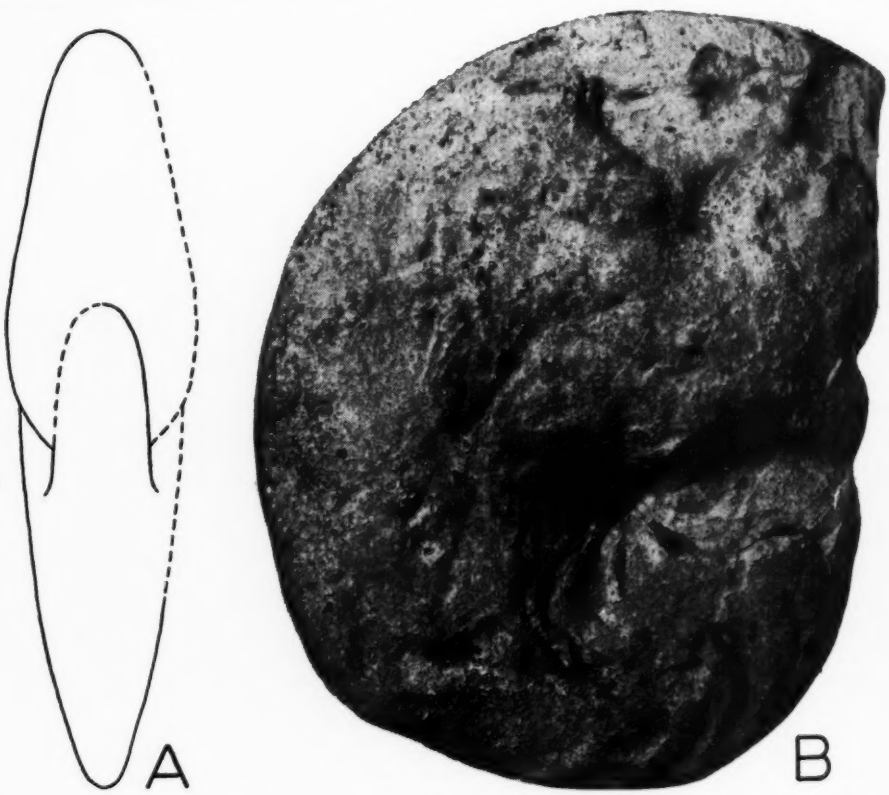
The conch is large and is discoidal in shape. The adoral three-fifths of the outer volution is non-septate and presumably represents most of the living chamber, but the specimen is not complete adorally. The greatest diameter, measured across the umbilicus is 15 cm.; the greatest thickness (restored) is 3.7 cm. No trace of ornamentation is preserved.

The umbilicus is open with a shoulder to shoulder diameter of 1.3 cm., which equals an eleventh the diameter of the specimen. The umbilical shoulders are subangular where well preserved. The protoconch and first whorls are not preserved so the exact shape and depth of the umbilicus is not known.

The septa are spaced so that there are 12 or 13 chambers in the adoral half-whorl of the phragmacone. The adoral sutures characteristically show a deep, narrow ventral lobe and on either side of it a rather small, asymmetrically V-shaped ventrolateral saddle, a deep, broadly rounded lateral lobe, and a similar but somewhat smaller lateral saddle. The fourth, fifth, and sixth sutures from the dorsal end are best preserved, but none of these can be traced dorsad of the umbilical shoulder. Some of the earlier sutures show a slight recurvature in the umbilicus which marks the beginning of the dorsolateral lobe.

The siphuncle was not observed.

Three additional specimens from the same horizon are tentatively referred to the same




TEXT-FIG. 1—*Tornoceras* cf. *T. buttsi* Miller. Ventral outline and lateral view of specimen from Nedrow member of Onondaga limestone, central New York, ×⅔.

species. One of these is from the locality of the described specimen and the others are from localities 1 and 8 miles away. None show any sutures. The first is a fragment of a specimen the size of the one described; the second is half of a somewhat larger internal mold, 17 cm. in diameter; and the third is an internal mold of the living chamber of a specimen 13–14 cm. in diameter.

*Remarks.*—The sutures of the described specimen are similar to those of *Tornoceras buttsi* Miller (1938, p. 147–148, text fig. 31, pl. 33, fig. 1), from a comparable horizon (lower Romney formation) in Virginia. The species was based on a single specimen of small diameter (6.5 cm.) which Miller (p. 148) believed to represent a late mature individual because of the comparatively short adoral camera. The last 2 septa are 2.5 mm. apart whereas preceding septa are spaced at 4–5 mm. intervals. In addition, Miller tentatively referred a second specimen (from Maryland) to the same species, This individual has a diameter of 3.2 cm. but is not well preserved.

The Onondaga specimen has all the characters of the genus *Tornoceras*, but is clearly separable from all other species of the genus, except *T. buttsi*, on the basis of the suture pattern. It differs from *T. buttsi* in its large size. It is perhaps more than just coincidental that the two Romney shale specimens are small (6.5 and 3.2 cm. diameters) while three other poorly preserved forms from the Onondaga limestone are comparable in size to the specimen herein described (13–17 cm. diameters). However, it seems best to compare the Onondaga forms with the existing species rather than establish a new one on such evidence.

*Occurrence.*—The first 3 specimens and probably the fourth are from the Nedrow member of the Onondaga limestone in the Richfield Springs 15 minute quadrangle, New York. The figured individual and one other were secured in a small gorge just south of the Oliver cemetery, 0.8 miles south of East Springfield, East Springfield 7½ minute quadrangle, by Dr. L. V. Rickard of St. Lawrence University, while collecting with the writer. The third specimen was found by the writer in outcrops 0.6 miles east of East Springfield. The fourth was noted by Rickard lying loose at a locality some 8 miles from the other two and was collected a year later by Rickard and the writer. Its situation and matrix lithology suggest that it is from the Nedrow member.

The described specimen has been deposited in the New York State Museum where it is numbered 10786. The other three specimens will be kept in the same repository.

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JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 2, P. 406–411, MARCH 1956

# REVIEWS

Two numbers of FOSSILIUM CATALOGUS II: *Plantae* have appeared recently under the continued editorship of W. Jongmans: Pars 28 (by W. Jongmans), *Filicales, Pteridospermae, Cycadales* (1955) and Pars 29 (by F. M. Wonnacott), *Celastraceae* (1955).

Part 28 is a continuation of the ferns, seed-ferns and cycads which was initiated in Part 27, the latter being the first number to appear after the delay caused by the war years. Part 28 begins with *Adiantites lindsaeaformis* and concludes with *Alcicornopteris* which indicates the huge volume of material that will ultimately appear under this large and difficult assemblage of fossils. The problems of preparing and editing so voluminous a manuscript can be fully appreciated only by one who has undertaken such a task; it would, however, certainly be advantageous if the remainder of this could appear as a unit rather than as small parts scattered through contributions dealing with unrelated plants groups.

Part 29 continues the same fine standards set by Mr. Wonnacott (in collaboration with Mr. W. N. Edwards) in Parts 14 and 20. Wonnacott has followed the form of many (but not all) of the previous numbers of Fossilium Catalogus in segregating his Bibliography (pages vii–xxv) from the Catalogue (pages 1–123); in view of the way the references are cited in full I believe that this is the preferable method. Twenty-six genera attributed to the Celastraceae are recorded, with more than half of the 400 species falling in the leaf genera *Celastrus* and *Celastrophyllum*. Also included are four petrified wood genera and a few based on fruits and flowers.

The locality of origin, horizon and present deposition is given for each species and a final section of the volume shows the geographical distribution of the fossil species by countries and states (within the U. S.). In the author's words: "No attempt has been made to deal with all the species critically but occasional comments have been made and where the species include references to fruits and woods etc. mention has been made accordingly." Mr. Wonnacott has prepared a contribution that might well serve as a standard for the remaining Parts of Fossilium Catalogus.

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ABOUT DYNAMICS OF SEPTAL DEVELOPMENT IN TETRACORALS DURING ONTOGENY by K. G. Voynovskiy-Kriger, Moskov. Obshch. Ispytateley Prirody Byull., Otdel Geol., tom 29, no. 5, p. 51–64, 1954.

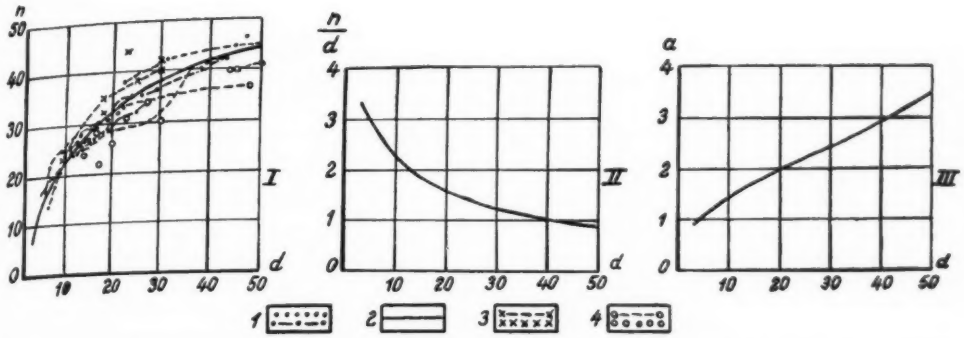
The septa of Paleozoic tetracorals are considered the most important part of their skeletons; and different phylogenetic branches are distinguished on the basis of type of septa. Up to the date of this report, however, the rate of septal development had remained unknown.

The number of septa in corals is considered a very important diagnostic feature. The diameter of the coral, however, must be also considered simultaneously, because the number of septa increases with coral growth. As a result, some paleontologists attempted to use the septal coefficient (number of septa per 1 mm. of cross section) for identification of corals. It is very easy to show, however, that the use of septal coefficients will lead to erroneous results, because the septal coefficient changes with coral growth.

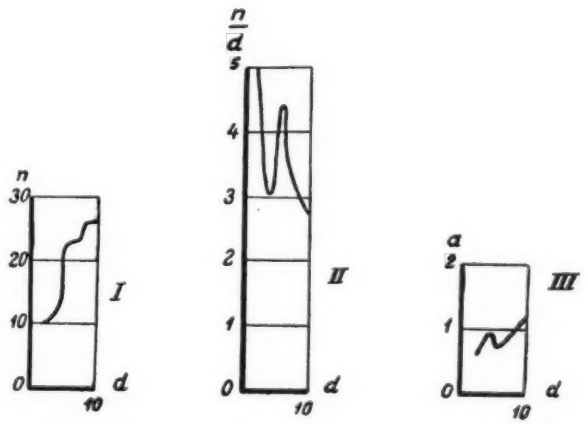
Choosing a diameter of one size (for example, 10 mm.), and calculating the number of septa for this particular cross section in all cases, would not improve the situation, because corals in the adult stage differ markedly in size. In some corals this diameter will correspond to maturity, and in others, to youth.

The Soviet paleontologists, therefore, do not use the septal coefficients. Instead, they tabulate the diameters of corals at different stages of growth and the corresponding number of septa.

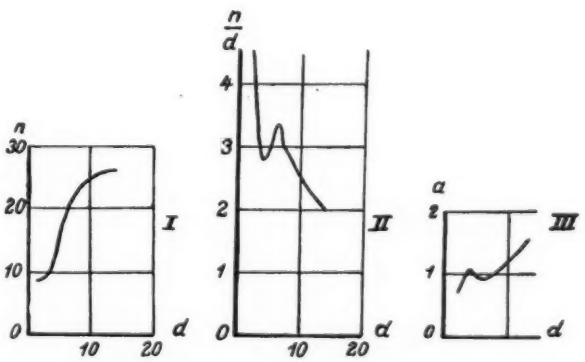
Voynovskiy-Kriger constructed diagrams which show the rate of septal development in tetracorals (Text-fig. 1–9; each consisting of Curves I, II, and III. All from Voynovskiy-Kriger). In all cases, the average diameter of corals, or the diameter of the "average zone" when the septa do not reach the outer



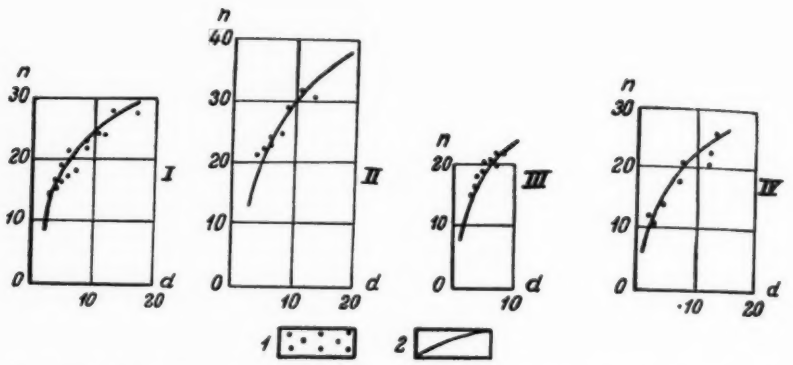

TEXT-FIG. *1*—Dynamics of septal development in *Caninia inostranzewi* (after Dobrolyubova, 1952). *n*—number of septa; *d*—diameter in mm.; *a*—distance in mm. between 1st order septa at outer periphery; *1*, curves of development of single individuals; *2*, average curve for *Caninia inostranzewi*; *3*, individual values and curves showing development of specimens with frequent septa; and *4*, individual values and curves showing development of specimens with sparse septa.



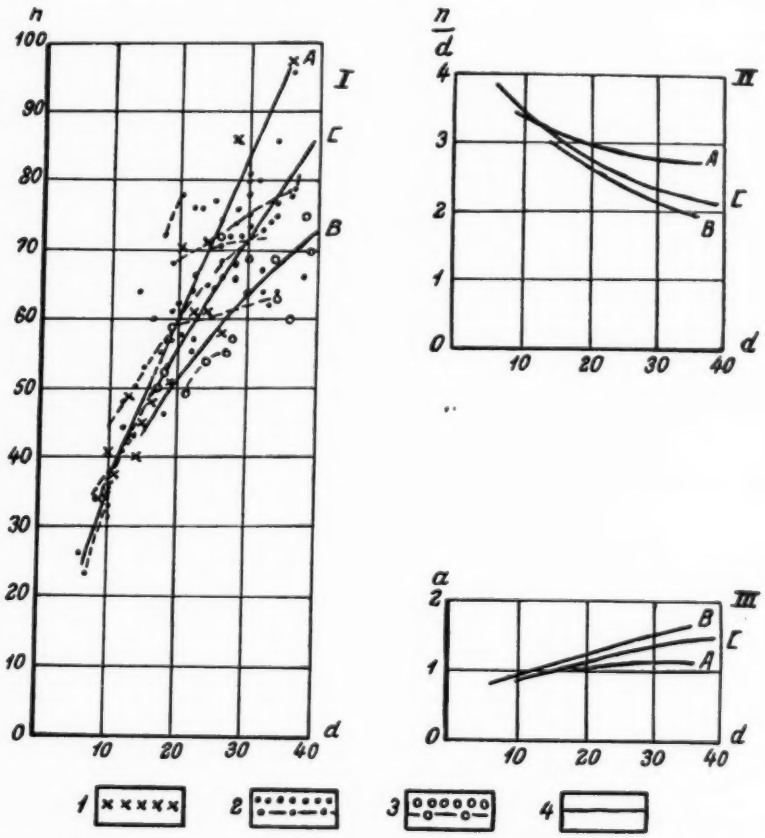

TEXT-FIG. *2*—Septal development in *Micula antiqua* (after Sytova, 1952).



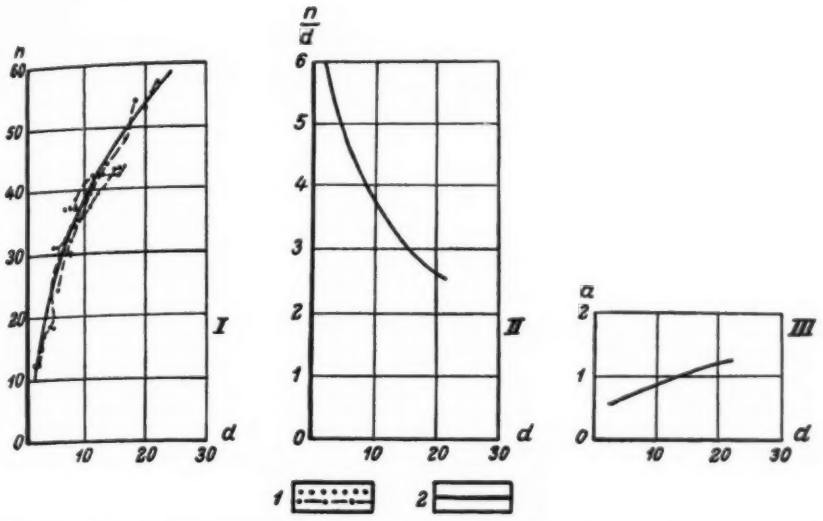

TEXT-FIG. *3*—Septal development in *Kyphophyllum lindströmi* (after Sytova, 1952).




TEXT-FIG. 4—Septal development in *Caractophyllum elongatum* (I), *Macgea solitaria* (II), *Pseudo bradyphyllum nikitini* (III), and *Botrophyllum conicum* (IV). After Soshkina (1949, 1951) and Dobrolyubova (1940). *1*, Individual values. *2*, Average curves.




TEXT-FIG. 5—Septal development in *Cyathoclisia coniseptum* and *Cyathoclisia* ex gr. *tabernaculum* (after Voynovskiy-Kriger, 1954). *1*, Individual values for specimens of *Cyathoclisia* ex gr. *tabernaculum*. *2*, Individual values and curves of development of separate individuals of *Cyathoclisia coniseptum*. *3*, Same as No. 2 for *Cyathoclisia coniseptum* forma *biseptata*. *4*, Average curves: *A*, *Cyathoclisia tabernaculum*, *B*, *Cyathoclisia coniseptum* forma *biseptata*, and *C*, *Cyathoclisia coniseptum*.




TEXT-FIG. 6—Septal development in *Palaeosmilia murchisoni* (after Kabakovich, 1952). *1*, Curves showing development of individual specimens. *2*, Average curves.

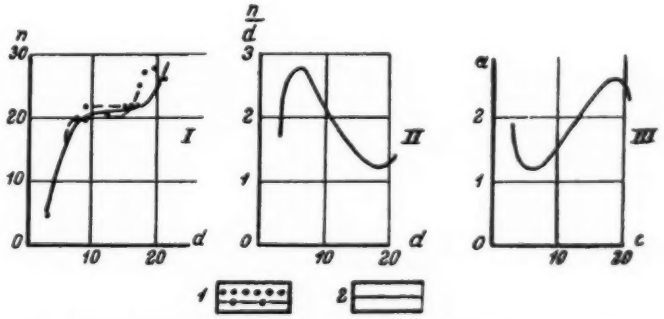
wall, was plotted on the abscissa. In constructing Curve I, the number of 1st order septa ($n$) was plotted on the ordinate; whereas the septal coefficient ($n/d$) was plotted on the ordinate in preparing Curve II, to show the changes in septal coefficient with growth of the coral.

In constructing Curve III, Voynovskiy-Kriger plotted the distance between two adjacent septa of 1st order (in mm.) on the ordinate. This distance is designated as "$a$" ($=\pi d/n$) and is inversely proportional to the septal coefficient ($n/d$). The septal coefficient, therefore, will remain constant only if the distance "$a$" does not change during the growth of the coral, which is unlikely.

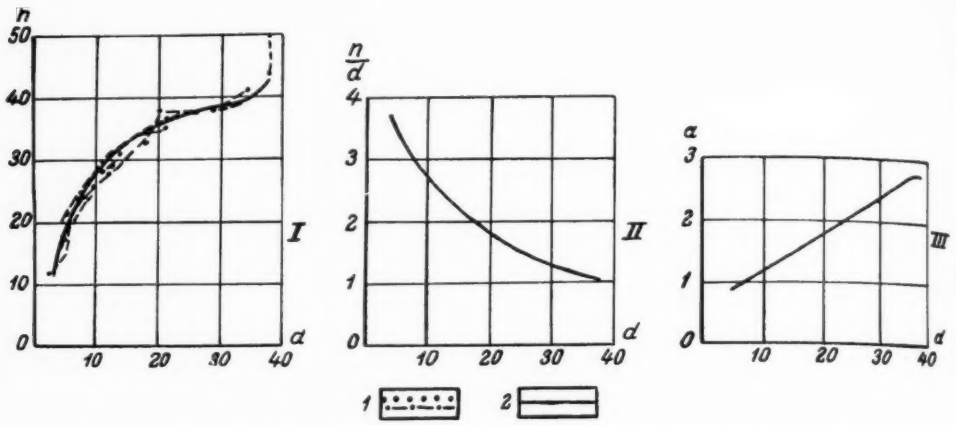
Some scattering of points in Curve I is probably indicative of individual variations of corals. The Curves II and III, on the other hand, were plotted on the basis of values taken from the average smooth Curve I (for diameters equal to 2, 5, 10, 15, 20, and 25 mm.).

An examination of Curve I in the text-figures led Voynovskiy-Kriger to make the following observations:

1. In some corals (*Kyphophyllum lindströmi* Wdkd., *Micula antiqua* Sytova, and, possibly, *Gshelia rouilleri* Stuck.) one can rarely observe an early stage of septal development with relatively slow increase in the number of septa. Voynovskiy-Kriger proposed to call this stage "adolescent" (nepionic) (Text-fig. 2,3).
2. The second stage, which is called "youth-




TEXT-FIG. 7—Septal development in *Stenophyllum uralicum* (after Soshkina, 1949). *1*, Curves showing development of individual specimens. *2*, Average curves.




TEXT-FIG. 8—Septal development in *Gshelia rouilleri* (after Dobrolyubova, 1940). *1*, Curves showing development of individual specimens. *2*, Average curves.

ful" (neanic) by Voynovskiy-Kriger, is characterized by the rapid rate of increase in the number of septa (steep portions of Curve I). This stage probably reflects the need of a growing coral to increase stability.

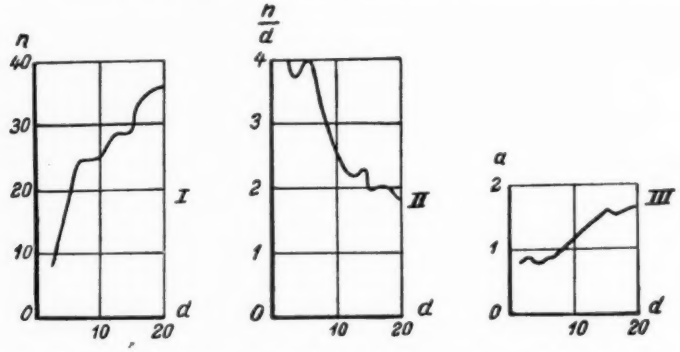
3. The number of septa gradually increases during the third stage, called "mature" (ephebic) by Voynovskiy-Kriger. The rate of increase, however, decreases progressively; evidenced by the convexity of Curve I. In only *Tabulophyllum gorskyi* (Bulv.), *Cyathoclisia* ex gr. *tabernaculum* Dingw., and *Bothrophyllum conicum* Trd. do the mature portions of Curves I approach a straight line. In these cases, the relationship between the diameter and number of septa can be expressed as simple formulas. For example: *Cyathoclisia* ex gr. *tabernaculum* $n \sim 13.5+2.37\ d$, where "*d*" is expressed in mm.

4. Curve I becomes almost parallel to the abscissa (Text-fig. 2,3) during the last stage, which was called "old" (gerontic) by Voynovskiy-Kriger. Although the diameter continues to increase during this stage, the number of septa remains constant or increases very slowly. Obviously, during the "old" stage the distance between the adjacent septa increases markedly.

The "old" stage was observed in *Kyphophyllum lindströmi* Wdkd., *K. elkiense* Sytova, *Entelophyllum uralicum* (Soshk.), *Neostringophyllum pronini* Soshk., *Pseudopetraia devonica* (Soshk.), some specimens of *Palaeosmilia murchisoni stutchburyi* Edw. et Haime, possibly *Pseudamplexus ligeriensis* (Barrois), and others.

Curve II in Text-fig. 1–3,5–9 shows the variation of septal coefficient with increasing diameter. In all cases, the septal coefficient decreases rapidly with coral growth.

The septal coefficient reaches the highest value in corals of the "multiseptata" group (with numerous septa; in some forms the number of septa reaches 100 at a diameter of




TEXT-FIG. 9—Septal development in *Entelophyllum uralicum* (after Sytova, 1952).

TABLE 1.—SEPTAL COEFFICIENT ($n/d$) AND DISTANCE BETWEEN 1ST ORDER SEPTA ($a$) IN DIFFERENT CORALS

| Name of coral | $n/d$ | | $a$ | | Group |
|---|---|---|---|---|---|
| | Youth | Maturity | Youth | Maturity | |
| *Caninia inostranzewi* Stuck. | 3.3 | 0.8 | 0.9 | 3.5 | oligoseptata |
| *Tachylasma aster* var. *rizoides* Soshk. | 3.5 | 1.3 | 0.9 | 2.3 | |
| *Stenophyllum uralicum* Soshk. | 3.0 | 1.3 | 1.1 | 2.5 | |
| *Amplexocarinia muralis* (Soshk.) | 5.0 | 2.4 | 0.6 | 1.6 | mesoseptata |
| *Gangamophyllum mosquense* Dobr. | — | 2.2 | — | 1.45 | |
| *Gangamophyllum boreale* Gorsky | — | 1.55 | — | 1.98 | |
| *Gshelia rouilleri* Stuck. | 4.7 | 1.1 | 0.7 | 2.75 | |
| *Palaeosmilia murchisoni* Edw. et Haime | 6.0 | 2.5 | 0.5 | 1.2 | multiseptata |
| *Cyathoclisia* ex gr. *tabernaculum* Dingw. | 3.4 | 2.7 | 0.8 | 1.15 | |

35 mm.), and lowest in the "oligoseptata" group (with few septa; the number of septa at a diameter of 15 mm. does not exceed 28). The septal coefficients of the "mesoseptata" group (intermediate in number of septa between the "multiseptata" and "oligoseptata" groups) occupy an intermediate position (Table I).

In all corals studied by Voynovskiy-Kriger, the septal coefficient ranged from 3.0 to 8.0 in youth and 0.8 to 2.75 at maturity.

The examination of Curves III, which show the relationship between distance "$a$" and the diameter of corals, reveals that the distance "$a$" is continuously increasing with growth of the coral. The rate of this increase is rapid (steep curves) in the corals of the "oligoseptata" group, and slow in corals of the "multiseptata" group. In some corals of the "multiseptata" group, Curve III asymptotically approaches the horizontal line (Text-fig. 5, III A), which indicates that the distance between the 1st order septa approaches a constant value.

In maturity, the distance "$a$" reaches 2.3–3.5 mm. in the "oligoseptata" group, and 1.0–1.2 mm. in corals of the "multiseptata" group. The distance "$a$" of the "mesoseptata" group of corals occupies an intermediate position.

Voynovskiy-Kriger observed that the 2nd order septa develop when the diameter is equal to 1.4 to 12 mm. (avg. 6.0 mm.) and the number of the 1st order septa ranges from 9 to 28 (avg. 17). The corresponding distance "$a$" ranges from 0.5 to 1.60 mm. (0.95 mm. avg.).

It seems that the 2nd order septa are introduced only when distance "$a$" is excessive and the coral needs further strengthening. Voynovskiy-Kriger also observed that the 2nd order septa are introduced at the same four points as the septa of 1st order, and do not all form at the same time.

The irregularities exhibited by the Curves I, II, and III in Text-figure 9 are probably due to the fact that *Entelophyllum uralicum* is characterized by the irregular narrowing and swelling of the cup.

*Conclusions.*—The graphic representation of the septal development in corals proposed by Voynovskiy-Kriger will be of great value in establishing genetic relationships between the various groups of corals. In some cases, the diagrams can also be used to differentiate a small but completely mature specimen from one in a "youthful" stage.

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——, 1952, *Caninia inostranzewi* Stuck. from Steshevskiy horizon of lower Carboniferous of Podmoskovnyy basin: *ibid.*, tom 40.

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SOSHKINA, E. D., 1949, Devonian Rugosa corals from Ural: *ibid.*, tom 15, vypusk 4.

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GEORGE V. CHILINGAR
University of Southern California

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 2, PP. 412–415, MARCH 1956

# SOCIETY RECORDS AND ACTIVITIES

## PROGRAM FOR S.E.P.M., CHICAGO MEETING (Conrad Hilton Hotel)

Robert R. Shrock, Technical Program Chairman

### SUMMARY OF PROGRAM

SUNDAY, APRIL 22

| | |
|---|---|
| *Registration* | ALL DAY |
| *S.E.P.M. Council* | 2 P.M. |

MONDAY, APRIL 23

| | |
|---|---|
| *Registration and Committee Meetings*, Grand Ballroom | 9 A.M. |
| *Research Committee Symposium: Directional Properties of Sedimentary Rocks*, Grand Ballroom | 1:45 P.M. |
| *Special Panel Session: Discussion of Topics Covered by Symposium*, Follows Immediately | |
| *Meeting of Research Committee* | 5:00 P.M. |

TUESDAY, APRIL 24

| | |
|---|---|
| *Joint Session with A.A.P.G.; Addresses, Honors, and Awards*, Grand Ballroom | 9:00 A.M. |
| *General Paleontology and Stratigraphy*, Waldorf Room | 1:45 P.M. |
| *Annual Business Meeting*, Waldorf Room | 4:30 P.M. |

WEDNESDAY, APRIL 25

| | |
|---|---|
| *Symposium on Paleoecology*, Waldorf Room | 9:00 A.M. |
| *Mineralogy and Sedimentary Petrology*, Waldorf Room | 1:45 P.M. |
| *Annual Dinner Dance* | EVENING |

THURSDAY, APRIL 26

| | |
|---|---|
| *Mineralogy and Sedimentary Petrology*, Waldorf Room | 9:00 A.M. |
| *General Paleontology and Stratigraphy*, Waldorf Room | 1:45 P.M. |
| *Meeting of New S.E.P.M. Officers* | 4:00 P.M. |

## SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS PROGRAM FOR 30TH ANNUAL MEETING

MONDAY, APRIL 23 — 1:45 P.M.

Grand Ballroom, Conrad Hilton Hotel

### RESEARCH COMMITTEE SYMPOSIUM: DIRECTIONAL PROPERTIES OF SEDIMENTARY ROCKS

Part I, Presentation of Papers

1. INTRODUCTION, Raymond Siever, Illinois State Geological Survey, Urbana, Illinois
2. FLUME EXPERIMENTS ON THE PRODUCTION OF STRATIFICATION AND CROSS-STRATIFICATION, Edwin D. McKee, U. S. Geological Survey, Washington, D. C.
3. SAND-GRAIN ORIENTATION AND GEOLOGICAL APPLICATION, Gene A. Rusnak, Scripps Institution of Oceanography, La Jolla, California
4. GRAIN ORIENTATION STUDIES OF RECENT SANDS, Joseph R. Curray, Scripps Institution of Oceanography, La Jolla, California
5. DIRECTIONAL PROPERTIES OF SOME CALIFORNIA SANDSTONES, L C. Bonham, California Research Company, La Habra, California
6. ORIENTED PHENOMENA PRODUCED BY SEDIMENTATION FROM TURBIDITY CURRENTS AND IN SUBAQUEOUS SLOPE DEPOSITS, John E. Sanders, Yale University, New Haven, Connecticut
7. TRACING TURBIDITY CURRENT DEPOSITS DOWN THE SLOPE OF AN ALPINE BASIN, Albert Carozzi, University of Illinois, Urbana

Part II, Panel Discussion

Discussion of each paper will be deferred until all papers have been presented.

TUESDAY, APRIL 24 9:00 A.M.

Grand Ballroom, Conrad Hilton Hotel

JOINT SESSION WITH AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS AND SOCIETY OF EXPLORATION GEOPHYSICISTS

Addresses, Honors, and Awards

*Presiding for S.E.P.M.:* J. Marvin Weller, University of Chicago

IN DEFENSE OF OUTDOOR GEOLOGY
Francis J. Pettijohn, President, Society of Economic Paleontologists and Mineralogists

PRESENTATION OF S.E.P.M. AWARDS
Raymond Siever, Illinois State Geological Survey
Best Paper in 1954 in Journal of Paleontology
*Recipient:* Donald Parkinson, Birmingham, England
Best Paper in 1954 in Journal of Sedimentary Petrology
*Recipients:* H. N. Fisk, E. McFarlan, Jr., C. R. Kolb, and L. J. Wilbert, Jr. (Deceased); Houston, Texas, Houston, Texas, and Vicksburg, Mississippi

S.E.P.M. HONORARY MEMBERSHIP
J. Marvin Weller
*Recipient:* Raymond C. Moore, University of Kansas

TUESDAY, APRIL 24 1:45 P.M.

Waldorf Room, Conrad Hilton Hotel

GENERAL PALEONTOLOGY AND STRATIGRAPHY

1. ECOLOGICAL INTERPRETATION OF THE PLIOCENE AND PLEISTOCENE STRATIGRAPHY IN THE GREAT PLAINS REGION, John C. Frye & A. Byron Leonard, Illinois State Geological Survey, Urbana, Illinois; University of Kansas, Lawrence, Kansas
2. PROBLEM OF SCIENTIFIC NOMENCLATURE APPLICABLE TO FRAGMENTARY FOSSILS, Raymond C. Moore & P. C. Sylvester-Bradley, University of Kansas, Lawrence, Kansas; University of Sheffield, Sheffield, England
3. SIGNIFICANCE OF LIVING FORAMINIFERAL POPULATIONS ALONG THE CENTRAL TEXAS COAST, Fred B. Phleger, Scripps Institution of Oceanography, La Jolla, California
4. PALEOECOLOGY OF THE FLORIDA MIOCENE, Harbans S. Puri & Robert O. Vernon, Florida Geological Survey, Tallahassee, Florida
5. RECENT AND ANCIENT PENETRANTS, Maxim K. Elias, University of Nebraska, Lincoln, Nebraska
6. SEDIMENTARY REFLECTIONS OF THE DEPOSITIONAL ENVIRONMENT IN A COASTAL LAGOON, Harris B. Stewart, Jr., Scripps Institution of Oceanography, La Jolla, California
7. MARINE ECOLOGY AS AN AID IN THE TEACHING OF INVERTEBRATE PALEONTOLOGY AND STRATIGRAPHY, William H. Mathews, III, Lamar State College of Technology, Beaumont, Texas

WEDNESDAY, APRIL 25 9:00 A.M.

Waldorf Room

SYMPOSIUM: PALEOECOLOGY

1. INTRODUCTORY REMARKS, Robert R. Shrock, Massachusetts Institute of Technology, Cambridge, Massachusetts
2. PLAN OF SYMPOSIUM, Harry S. Ladd, U. S. Geological Survey, Washington, D. C.
3. MARINE LEVEL-BOTTOM ANIMAL COMMUNITIES OF RECENT SEAS, Gunnar Thorson, Copenhagen Zoological Museum, Copenhagen, Denmark
4. CONDITIONS OF LIFE IN THE SEA, Joel W. Hedgpeth, Scripps Institution of Oceanography, La Jolla, California
5. PALEOECOLOGICAL EVIDENCE FURNISHED BY FOSSILS, Harry S. Ladd, U. S. Geological Survey, Washington, D. C.
6. PALEOECOLOGICAL EVIDENCE FROM SEDIMENTS, Bernhard Kummel, Harvard University, Cambridge, Massachusetts
7. DIATOMS AS PALEOECOLOGICAL INDICATORS, Kenneth E. Lohman, U. S. Geological Survey, Washington, D. C.
8. NEW TECHNIQUES IN PALEOECOLOGY, Philip H. Abelson, Geophysical Laboratory, Carnegie Institution of Washington, Washington, D. C.

WEDNESDAY, APRIL 25 1:45 P.M.

Waldorf Room

MINERALOGY AND SEDIMENTARY PETROLOGY

1. UNIFORMITARIANISM IS A DANGEROUS DOCTRINE, Paul D. Krynine, The Pennsylvania State University, University Park, Pennsylvania

2. TERTIARY REEF LIMESTONES FROM SOUTHERN LOUISIANA AND GUAM, McLain J. Forman & Seymour O. Schlanger, c/o Gordon Atwater, consulting geologist, New Orleans, Louisiana; U. S. Geological Survey, Washington, D. C.
3. REVISIONS IN THE MINERALOGY OF THE FUNAFUTI DRILL CORES AND THEIR BEARING ON THE PHYSIOCHEMISTRY OF DOLOMITE, Robert F. Schmalz, Army Chemical Center, Maryland
4. HEAVY-MINERAL ASSEMBLAGES OF THE CORAL-REEF LIMESTONES AT THE BASE OF THE TRICHINOPOLY CRETACEOUS (CENOMANIAN TO DANIAN), SOUTH INDIA, G. Gundu Rao, The Pennsylvania State University, University Park, Pennsylvania
5. PETROGRAPHY AND GENESIS OF THE OGALLALA "ALGAL LIMESTONE" IN KANSAS AND ADJACENT STATES, Ada Swineford, John C. Frye, & A. Byron Leonard, State Geological Survey of Kansas, Lawrence, Kansas; Illinois State Geological Survey, Urbana, Illinois; University of Kansas, Lawrence, Kansas
6. SHELF-EDGE, CALCAREOUS PROMINENCES IN THE NORTHEASTERN GULF OF MEXICO, John C. Ludwick & William R. Walton, Gulf Research and Development Company, Houston, Texas
7. SILURIAN REEFS OF THE NORTHERN EDGE OF THE EASTERN INTERIOR BASIN, John B. Sangree, Jr., Northwestern University, Evanston, Illinois
8. TRANSITIONAL PERMO-PENNSYLVANIAN SEDIMENTS OF THE ROWE-MORA BASIN, NEW MEXICO, Raymond Sidwell & G. Frederick Warn, Texas Technological College, Lubbock, Texas

THURSDAY, APRIL 26 9:00 A.M.

Waldorf Room

MINERALOGY AND SEDIMENTARY PETROLOGY

1. ALICE IN GRAYWACKELAND, Paul D. Krynine, The Pennsylvania State University, University Park, Pennsylvania
2. RELATION OF PETROLOGY AND STRUCTURE TO PRODUCTIVITY IN A STRATIGRAPHIC TRAP, LINDEMANN (McMILLAN SAND) OIL FIELD, RUNNELS COUNTY, TEXAS, Morton K. Blaustein, Midland, Texas
3. PERMEABILITY LOSS FROM SWELLING OF MATRIX CLAYS IN SUB-GRAYWACKES, G. Harvey Hamilton & George R. Downs, Union Oil Company of California, Denver, Colorado; Consulting Geologist, Denver, Colorado
4. DIFFERENTIAL COMPACTION OF PENNSYLVANIAN SEDIMENTS IN RELATION TO SAND-SHALE RATIOS, JEFFERSON COUNTY, ILLINOIS, Joseph C. Mueller & Harold R. Wanless, Continental Oil Company, Oklahoma City, Oklahoma; University of Illinois, Urbana, Illinois
5. CLAY-MINERAL COMPOSITION OF RECENT SEDIMENTS FROM THE MISSISSIPPI RIVER DELTA, W. D. Johns, Jr., & R. E. Grim, University of Illinois, Urbana, Illinois
6. ENVIRONMENTAL CONDITIONS AFFECTING THE DEPOSITION OF BEACH SANDS BETWEEN VIRGINIA AND FLORIDA, Suzanne F. Bershad & John K. Duncan, Division of Oceanography, U. S. Navy Hydrographic Office, Washington, D. C.
7. MIDDLE PALEOZOIC TECTONIC HISTORY OF NORTH-CENTRAL AND NORTHWESTERN UTAH, James E. Brooks, Southern Methodist University, Dallas, Texas
8. TRIASSIC IN THE EASTERN GREAT BASIN, David L. Clark & William Lee Stokes, University of Iowa, Iowa City, Iowa; University of Utah, Salt Lake City, Utah

THURSDAY, APRIL 26 1:45 P.M.

Waldorf Room

GENERAL PALEONTOLOGY AND STRATIGRAPHY

1. THE IDENTIFICATION OF OSTRACODE GENERA AND SPECIES IN THIN SECTIONS, Stuart A. Levinson, Humble Oil & Refining Company, Houston, Texas
2. A FAUNULE OF UNUSUAL NONMARINE OSTRACODA FROM THE PLIOCENE OF IDAHO, Daniel J. Jones & Norman R. Anderson, University of Utah, Salt Lake City, Utah
3. CONODONTS FROM THE TYPE CHESTER, ILLINOIS, Carl B. Rexroad, Texas Technological College, Lubbock, Texas
4. UPPER DEVONIAN SUBSTAGES AND THEIR WORLD-WIDE CORRELATION ON THE BASIS OF CONODONTS, Klaus J. Müller, State University of Iowa, Iowa City, Iowa
5. SPECIFIC VARIATIONS AMONG ARENACEOUS SILURIAN FORAMINIFERA FROM ILLINOIS, Howard Schwalb & Charles Collinson, Illinois State Geological Survey, Urbana, Illinois
6. *ACANTHOCLADIA GUADALUPENSIS* GIRTY, A POSSIBLE ALGAL-BRYOZOAN SYMBIOT, J. Keith Rigby, Brigham Young University, Provo, Utah
7. DENDRASTER: A PROBLEM IN ECHINOID TAXONOMY, D. M. Raup, Harvard University, Cambridge, Massachusetts

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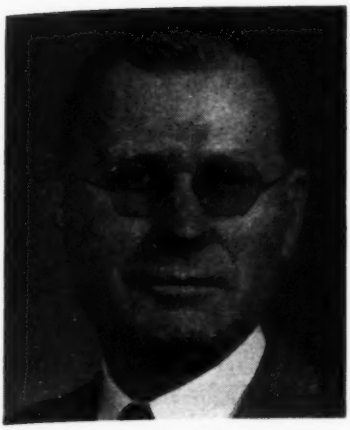

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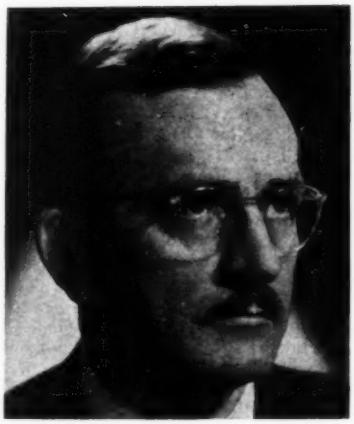

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JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 2, P. 416–442, MARCH 1956

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Furnish, William M.
Miller, A. K.
Tester, Allen C.
Trowbridge, A. C.

KANSAS

Independence—
Studt, Charles W.
Kansas City—
Hawkins, Harold H.
Lawrence—
Dellwig, Louis Field
Fay, Robert O.
Ireland, Hubert A.
King, Ralph H.
Laukel, Quinn C.
McManus, Dean A.
Merriam, Daniel Francis
Moore, Raymond C.
Swineford, Ada
Thompson, M. L.
Youngquist, Walter L.
Mission—
Bunch, Rosella L.
Wichita—
Batchelor, Jo Wolter
Carmody, Robert A.
Douglass, Harry Marvin
Koester, Edward A.
Rector, Glasco W.
Tasch, Paul
Walters, Robert F.
Zajic, William E.

KENTUCKY

Hopkinsville—
Nosow, Edmund

LOUISIANA

Baton Rouge—
Brockhouse, Robert B.
Camacho, Enrique
Cheetham, Alan H.
Delaney, Patrick J.
Durham, Clarence O., Jr.
Howe, Henry V.
Murray, Grover E.
Lake Charles—
Chatham, E. Walter, Jr.
Latta, Lee Allen
Morrow, A. Lyndon
Rudick, Walter James
Tabbert, R. L.
Taylor, Jack A.
Tipsword, Howard Lee
Warren, Albert D.
Lafayette—
Anderson, Irvin J.
Etter, John
Gimbrede, Louis de A.
Gooch, D. D.
Paine, William R.
Varvaro, Gasper Gus
Wiley, Richard A.
New Orleans—
Akers, Wilburn H.
Bane, M. Ray
Braunstein, Jules
Cameron, Donald K., Jr.
Clark, Robey H.
Ferguson, H. C.
Forman, McLain, Jr.
Morgan, Aylmer Lee, III
Philpott, Thomas H.
Slama, Don C.
Tonti, Edmond C.
Ruston—
Higgs, William R.
Shreveport—
Brown, Dwight M., Jr.
Craver, Frank S., Jr.
Danehy, Edward A.
Hazzard, Roy T.
Sprouse, Donald W.

MAINE

Orono—
Trefethen, Joseph M.

MARYLAND

Baltimore—
Fairley, William M.
Pettijohn, Francis J.
Beltsville—
Carroll, Dorothy
Hathaway, John S.
Bethesda—
Stephenson, Lloyd W.
Chevy Chase—
Ladd, Harry S.
Edgewood—
Bebout, Don G.
Hyattsville—
Reeside, John B., Jr.
Schultz, Hildreth N.
Kensington—
Dante, John Henry
Queenstown—
White, Maynard P.
Rockville—
McIntyre, John B.
Suitland—
Burns, Robert E.
Kaufman, Oscar

MASSACHUSETTS

Amherst—
Johansson, Warren Irving
Wilson, Leonard R.
Bedford—
Dott, Robert H., Jr.
Boston—
Hecht, Richard J.
Cambridge—
Barghoorn, Elso
Kummel, Bernhard
Mencher, Ely
Moore, James R., III
Shrock, Robert R.
Stetson, Henry C.
Natick—
Hubert, John F.
Northampton—
Shaub, Benjamin M.
Williamstown—
Ramsdell, Robert C.
Woods Hole—
Athearn, William D.

MICHIGAN

Ann Arbor—
Briggs, Louis I.
Kellum, Lewis B.
Landes, Kenneth K.
Detroit—
Sanford, John T.
East Lansing—
Kelly, William A.

MINNESOTA

Minneapolis—
Cornell, James R.
Goldich, Samuel S.
Holt, Olin R.

Sloan, Robert Evan
Swain, Fred M.
Northfield—
Stewart, Duncan

MISSISSIPPI

Hattiesburg—
West, Jesse W.
Jackson—
Adams, Emmett R.
Applin, Esther R.
Brown, Charles E.
Johnson, Wendell B.
Karges, Harold E.
Kirby, Louie C.
Mather, Katharine
Mellen, Frederic F.
Phillips, Scott, H.
Rainwater, E. H.
Scurlock, Clarence R.
Taylor, Waller E.
Tench, Robert Norman
Laurel—
Hughes, Urban B.
State College—
Smith, William H.
University—
Hughes, R. J., Jr.
Shaver, Robert H.
Vicksburg—
Van Lopik, Jack R.

MISSOURI

Columbia—
Bradley, Daniel A.
Keller, W. D.
Peck, Raymond E.
Unklesbay, Athel G.
Ferguson—
Echols, Dorothy Jung
Kansas City—
Greene, Frank C.
Rolla—
Frizzell, Don L.
St. Louis—
Brice, James Coble
Hinchey, Norman S.

MONTANA

Billings—
Beekly, Emerson K.
Darrow, George F.
Doroshenko, Jerry
Munyan, Arthur C.
Richards, Paul W.
Shepard, Herbert Warren
Sonnenberg, Frank P.
Stainforth, Robert M.
Great Falls—
Gribi, Edward A., Jr.

NEBRASKA

Lincoln—
Elias, Maxim K.
Lugn, Alvin L.
Reed, Eugene C.
Whelan, Thomas J., Jr.

NEW HAMPSHIRE

N. Conway—
Hattin, Donald E.
Portsmouth—
Sage, Nathaniel M., Jr.

NEW JERSEY

Glen Ridge—
Emery, John Rathbone
Hopewell—
Pierson, J. R., Jr.
New Brunswick—
Fox, Steven K., Jr.
Martens, James H. C.
Princeton—
Hess, Harry H.
Howell, B. F.
Van Houten, Franklyn B.
S. Orange—
Nine, Ogden W., Jr.

NEW MEXICO

Albuquerque—
Bourn, Oscar B.
Hayes, Philip T.
Thorp, Eldon M.
Wengerd, Sherman A.
Carlsbad—
Pratt, Wallace E.
Farmington—
Petty, John K.
Raymond, Paul C.
Roswell—
Ehlmann, Arthur J.
Fickman, Philip
McNulty, Charles L., Jr.
Meyer, Richard F.
Newsom, Y. B.
Shepard, R. H.
Sweeney, H. N.
Winkler, Hans
Socorro—
Pitrat, Charles W.

NEW YORK

Brooklyn—
Wang, Kia-Kang
Buffalo—
Hibbard, Raymond R.
Nadeau, Betty Kellett
Ithaca—
Palmer, Katherine V. W.
Mamaroneck—
Dresser, Hugh
New York—
Cruse, John S., Jr.
Dietz, Robert S.
Ellis, Brooks F.
Fairbridge, R. W.
Flagler, C. W.
Imbrie, John
Jaekel, Julie Ann
James, John W.
Kaufmann, Godfrey F.
Kay, Marshall
King, Robert Evans
Knebel, George Moses
Messina, Angelina R.
Newell, Norman D.
Page, Lou Williams
Schaffel, Simon
Terry, Jack S.
Thralls, Warren H.
Pittsford—
Alling, Harold L.
Poughkeepsie—
Johnsen, John H.
Warthin, A. S., Jr.
Rochester—
Sutton, Robert G.
Syracuse—
Apfel, Earl T.
Troy—
Beers, Roland F.
Lowman, Shepard W.
Williston—
Cochran, John A.

NORTH CAROLINA

Chapel Hill—
Ingram, Roy L.

NORTH DAKOTA

Bismarck—
Harris, Steven H.
Tudor, Mathew S.
Fargo—
Pye, Willard D.
Grand Forks—
Holland, Frank D., Jr.

OHIO

Athens—
Sturgeon, Myron T.
Cincinnati—
Abbott, Ralph E.
Caster, Kenneth E.
Columbus—
Leutz, Willard P.
Levinson, Alfred A.
Schopf, James M.
Spieker, Edmund M.
Summerson, Charles H.
Sweet, Walter C.
Weiss, Malcolm P.
Dayton—
Chilingar, George V.
Coryell, Horace N.
Oxford—
Martin, Wayne D.

OKLAHOMA

Ardmore—
Johnson, William R.
Neustadt, Walter, Jr.
Speer, John Hill
Tomlinson, Charles W.
Westheimer, Jerome Max
Wilson, Ruth B.
Bartlesville—
Hicks, I. Curtis
Passega, Renato
Strimple, H. L.
Weeks, Warren B.

Chickasha—
Bryan, J. Victor
Enid—
Baker, Vernon R.
Clifton, R. L.
Muir, J. Lawrence
Muskogee—
Wallace, Maurice H
Newkirk—
Schoonover, Jack G.
Norman—
Branson, Carl C.
Culp, Eugene F.
Curtis, Doris Malkin
Curtis, Neville, M., Jr.
Decker, Charles E.
Frederickson, Edward A.
Harris, Reginald W.
Huffman, George G.
Jordan, Louise
Lucas, Elmer Lawrence
Moore, Carl A.
Oklahoma City—
Adent, William A.
Blythe, Jack Gordon
Eisner, Stephen M.
Heyman, Louis
Isbell, Grover Jim
Jacobsen, Lynn
Kate, Frederick H.
McGee, Dean A.
Pasquella, George G.
Pollard, Robert T.
Reiter, Frederick H.
Tubb, George G.
Turk, Lon B.
Shawnee—
Phillips, David Lee
Stillwater—
Schreiber, Joseph F., Jr.
Tulsa—
Bennison, Allan P.
Bramlette, W. A.
Branson, Herberta Van Pelt
Busch, Daniel A.
Campbell, Charles V.
Connolly, Frank T.
Contreras, Carlos E.
Daetwyler, Calvin C.
Denison, A. Rodger
Ellsworth, Elmer W.
Enlows, Harold E.
Goldstein, August, Jr.
Grigsby, R. B.
Harlton, Bruce H.
Hawkins, Glenn D.
Hoffmeister, William S.
Hopkins, M. E.
Kauffman, James S.
Kjellesvig-Waering, E. N.
Kornfeld, Joseph A.
Levorsen, A. I.
Martin, James L., Jr.
Miller, Paul M.
Porterfield, Robert R.
Reeves, James E.
Rhoades, Sam J., Jr.
Ryniker, Charles
Sarmiento-Soto, Roberto
Scruton, Philip C.
Snider, James W.
Steele, Grant
Stephenson, Morton B.
Stone, Solon W.
Vernon, Roger C.
Wagner, Carl D.

OREGON

Corvallis—
Bostwick, David A.
Eugene—
Baldwin, Ewart M.
Bressler, Calder T.
Portland—
Stewart, Roscoe E.

PENNSYLVANIA

Bethlehem—
Willard, Bradford
Lancaster—
Moss, John Hall
Shepps, Vincent C.
Lewisburg—
Powers, Maurice C.
Philadelphia—
Weeks, H. J.
Pittsburgh—
Cox, Ben B.
Fettke, Charles R.
Hedberg, Hollis D.
Lattman, Laurence H.
Sass, Louis Carl
Sutton, A. H.
Tator, Benjamin A.
University Park—
Griffiths, J. C.
Krynine, Paul D.
Stanley, Edward A.
Swartz, Frank M.

RHODE ISLAND

Kingston—
Garrison, Louis Eldred
McMaster, Robert L.

SOUTH DAKOTA

Rapid City—
Tullis, Edward L.
Vermillion—
Agnew, Allen F.
Stevenson, Robert Evans

TENNESSEE

Memphis—
Marcher, Melvin V.

TEXAS

Abilene—
Conselman, Frank B.
Fountain, H. C.
Hada, John L.
Hayward, Charles W.
Morrison, Robert E.
Samuell, John Howard
Schenck, Walter L.
Amarillo—
Britt, Harry M., Jr.
Craig, Thomas C.
Tarver, Jack H.
Austin—
Adkins, W. S.
Amsbury, David L.
Barnes, Virgil E.
Bell, W. Charles
Damon, H. Gordon
Eartle, D. Hoye
Ellison, Samuel P., Jr.
Flawn, Peter T.
Folk, Robert L.
Grant, Richard E.
Gurel, Mehmet
Horton, Claude W.
Lonsdale, John T.
Mankin, Charles
Morey, Philip S.
Myers, Donald A.
Pittman, James S., Jr.
Twining, John T.
Whitney, F. L.
Young, Keith P.
Beaumont—
Beck, Frank Ralph
Eveland, Harmon E.
Matthews, William H., III
Strachn, Clarence H., Jr.
Beeville—
Conkin, James Elvin
Bellaire—
Caldwell, Barbara S.
Chun, Harold A.
Holliday, Samuel
Kilgore, John E.
Masson, Peter H.
Setzer, Francis M.
Breckenridge—
Pitzer, Phillip M.
Cedar Valley—
O'Hara, James F., Jr.
Coleman—
Rothrock, Howard E.
College Station—
Koenig, Karl J.
Lynch, Shirley A.
Smith, Fred E.
Corpus Christi—
Abrahamson, E. C.
Bannahan, Annabelle
Campbell, A. Richard
Clarkson, Louise Freeman
Cook, Theodore D.
Giltner, Robert F.
Higgins, Maurice J.
Holcomb, Charles W.
Krause, Erwin K.
Lohse, E. Alan
Middour, E. S.
Owens, Frith Cravens
Dallas—
Albritton, Claude C., Jr
Alexander, C. I.
Allen, John L.
Aschenbrenner, B. C.
Billingsley, Harold Ray

Bradfield, Herbert H.
Brooks, James E.
Clark, John W.
DeGolyer, E.
Doering, John A.
Dunlap, John B., Jr.
Frost, Jack
Fuqua, Irene Sribny
Green, Cecil H.
Grubbs, David M.
Haertlein, James A.
Hamilton, I. B.
Karcher, John C.
MacNaughton, Lewis W.
McCluer, Robert D.
McCommons, William E.
McLeod, Angus
Meyer, Willis G.
Montgomery, James H.
Moreman, Walter L.
Perkins, Bob F.
Richards, Arthur
Robertson, Herbert C., Jr.
Robinson, Van D.
Sellin, H. A.
Stehr, Raymond A.
Thompson, Sam, III
Thompson, S. A.
Tripp, R. Maurice
Wiggins, Peter N.
Williams, Harry F.
Williams, James R.
Wilson, Starkey
Woodard, Robert L.
Zimmerman, Donald A.

El Paso—
Baldwin, Don C.
Nelson, Lloyd A.

Fort Worth—
Cooley, Douglas R.
Donoghue, David
Harges, Marvin E.
Hendricks, Leo
King, William Edward
McBride, Mary Wood
McEachin, Wright D.
McKay, Alexander E.
Moore, Walter L.
Schweers, Richard H.
Stewart, Wendell J.

Galveston—
Artusy, Raymond L.

Gorman—
Brogdon, Dewey Robert

Houston—
Albers, Charles C.
Alexander, W. H., Jr.
Baker, William A., Jr.
Barker, R. Wright
Beach, Paul R.
Bell, Olin G.
Bernard, Hugh A.
Bright, Anna Lou
Brixey, Austin D., Jr.
Bush, James
Carstens, Fred D.
Colle, Jack O.
Consiglio, Louis A.
Cotton, Edgar A.
Cram, Ira H.
Croneis, Carey
Crouch, Robert W.
Denham, Richard L.
Deussen, Alexander
Dillingham, Hervie, Jr.
Ellis, Albert D., Jr.
Fan, Paul H.
Fisk, Harold N.
Garrett, J. B., Jr.
Goodrich, Paul K.
Griffin, George M.
Halbouty, M. T.
Halsted, Morris E.
Hanna, Marcus A.
Hornberger, Joseph, Jr.
Hsu, K. Jinghwa
Ikins, William C.
Jeffords, Russell M.
Kellough, Gene Ross
LeBlanc, Rufus J.
Levinson, Stuart A.
Lohman, Clarence, Jr.
Lozo, Frank E.
Ludwick, John C.
Major, C. Fred, Jr.
Malicoat, Arthur F.
Martyn, Phil F.
McFarlan, Edward, Jr.
Monaghan, Patrick H.
Montgomery, J. C.
Moody, Clarence L.
Morrison, T. E.
Munsey, Gordon C., Jr.
Nanz, Robert H., Jr.
Nelson, Paul Hugh
Nygren, Walter Eric
O'Malley, F. Ward
Overton, Charles K.
Parker, William G.
Parks, James M., Jr.
Payne, Thomas G.
Petrusek, Benjamin J.
Phillips, Henry H.
Pyeatt, Lloyd M.
Quigley, Claude M., Jr.
Reiter, W. A.
Reynolds, E. Julius
Rittenhouse, Gordon
Ritts, L. Chase, Jr.
Rolshausen, F. W.
Rotan, Cleone M.
Sawin, Horace J.
Scrafford, John Bruce
Selig, A. L.
Smith, Denver J.
Smith, Fred L., Jr.
Smith, William Thomas
Speed, Carlton D., Jr.
Stenzel, H. B.
Stevenson, Frank V.
Stubbs, Sidney A.
Stuckey, Charles W., Jr.
Sutherland, Patrick K.
Tatum, Emmett P.
Treadwell, Robert C.
Trimm, Warren M.
Walk, Hugh G.
Walter, Joe C., Jr.
Walton, William R.
West, Glen D.
Westmoreland, Frank S.
Whipple, G. Leslie
Wilson, James Lee
Wimberley, C. Stanley
Woods, Raymond D.

Karnes City—
Kirsch, M. Ivo, Jr.

La Pryor—
Grant, Drane Fones

Lubbock—
Arper, William B., Jr.
Brand, John Paul
Mattox, Richard B.
Rexroad, Carl B.
Sidwell, Raymond
Wade, F. Alton

McAllen—
Lalicker, Cecil G.
Means, John A.

Midland—
Adams, John Emery
Clarkson, Wm. G., Jr.
Crotty, Burns M.
Davis, Billy Glen
Ewbank, Norman Ware, Jr.
Frenzel, Hugh N.
Gibson, George R.
Hajek, Charles F.
Hitt, Jack L.
Hollingsworth, R. V.
Hull, J. P. D., Jr.
Kerr, S. Duff, Jr.
Keyser, Joseph E.
Leibrock, R. M.
Lovejoy, Bill P.
Luckett, Joseph W., Jr.
Madden, Lloyd Willis
Mills, Lloyd C.
Muery, Warren E.
Oppel, Richard Edward
Perusek, Cyril J.
Rindsig, Julia K.
Rodgers, Jack P.
Sanderson, George A., Jr.
Schmitt, George T.
Scobey, Ellis H.
Skinner, John W.
Spencer, Maria
Stead, Frederick L.
Taylor, Howard Dean
Toomey, Donald F.
Vogler, Edward A.
Warren, Walter C.
Wilde, Garner Lee
Williams, Harold L.

Odessa—
van West, F.

Port Aransas—
Bradley, John S.

Richardson—
Scull, Berton J.
Weart, Richard C.

San Angelo—
Gregory, Joseph N.

Murphy, Daniel J.
Rhodes, Mary Louise
San Antonio—
Fritz, Joe F.
Grasso, Volker C.
Magaw, Mary Catherine
Owen, Edgar W.
Petty, Dabney E.
Rogers, James K.
Sandidge, John R.
Siemer, William J.
Still, J. T.
Tartamella, Natale J.
Theessen, E. J.
Seagoville—
Waters, James A.
Seguin—
Kniker, Hedwig T.
Seymour—
Kemp, Augusta Hasslock
Spring—
Aves, Charles A.
Tyler—
Eaton, Robert Wesley
Hamberg, Lawrence R.
Hurlbut, Elvin M., Jr.
Nichols, Paul H.
Peters, Theodore C.
Raasch, Albert C., Jr.
Rees, Barbara Leigh
Uvalde—
Welder, Frank A.
Waco—
Turner, James, A., Jr.
Wichita Falls—
Davis, Charles E.
Dennis, Lyman C.
Drake, Robert T.
Richards, David T.
Tripp, Ethel Davis

UTAH

Moab—
Norman, Robert R.
Salt Lake City—
Barkell, Clifford A.
Darrow, Richard L.
Hill, John Davis
Jones, Daniel J.
Linville, Andrew F., Jr.
Lyon, Craig A.
Osmond, John C., Jr.
Peterson, James A.
Richards, H. Glenn
Schnurr, Paul Eugene
Stokes, William Lee
Turner, Francis E.
Weiss, Hans

VIRGINIA

Alexandria—
Goldman, Marcus I.
McLean, James D., Jr.
Charlottesville—
Young, Robert S.
Falls Church—
Palmer, Allison R.
Ft. Lee—
Price, Charles E., Jr.
Lexington—
Stow, Marcellus H.

WASHINGTON

Pullman—
Scott, W. Frank
Seattle—
Coombs, Howard A.
Fulmer, Charles V.
Gould, Howard R.
Mallory, V. Standish
Wheeler, Harry E.
Tacoma—
McMillin, Frederick A.

WEST VIRGINIA

Clarksburg—
Bayles, Robert E.
Morgantown—
Heald, Milton T.

WISCONSIN

Green Bay—
Riggs, Elliott A.
La Crosse—
Gehrig, John Leonard
Madison—
Cline, Lewis M.
Tyler, Stanley A.
Zeller, Edward J.

WYOMING

Basin—
Lease, Leslie W.
Casper—
Byrne, Frank E.
DeLong, Jack M.
Heacock, Robert L.
Little, Curtis J.
Mills, Norman K.
Peterson, Marvin L.
Storm, Paul V.
Swirczynski, Richard P.
Worland—
Hanson, Alvin M.

## OUTSIDE THE UNITED STATES

ALASKA

College—
Freeman, Val LeRoy

ALBERTA

Calgary—
Andrichuk, John M.
Atkinson, Eric
Burgers, Willem
Chakravorty, Sailendra
Chamney, T. Potter
Chilton, Mertie Ann
Crombie, Gordon P.
DeWit, Rein
Erickson, Robert H.
Fong, George
Goodman, A. J.
Hilgers, C. L. L.
Hunt, C. Warren
MacKay, Ian H.
McCrossan, R. G.
Moore, Peter F.
Raasch, Gilbert O.
Rogers, Michael A.
Slemko, William
Sproule, J. C.
Stewart, Grace Anne
Wegmuller, Walter
Wickenden, Robert T. D.
Williams, Edwin Philp
Wonfor, John S.
Workman, Lewis E.

ALGERIA

Alger—
Lucas, Gabriel
Magne, Jean
Termier, Henri

ANGOLA

Luanda—
Brognon, Georges P. G.
DeCarvalho, G. Soares

AUSTRALIA

Adelaide—
Glaessner, Martin Fritz
Canberra—
Burnett, W. M.
Crespin, Irene
East Brighton—
Wales, Darren W.
Melbourne—
O'Mara, Jarvis Hugh
Sydney—
Browne, Ida A.

AUSTRIA

Graz—
Flugel, Helmut
Vienna—
Kupper, Klaus
Schors, W. W. L.

BELGIAN CONGO

Leopoldville—
Zimmermann, Fritz R.

BELGIUM

Brussels—
Lombard, Augustin E.
Gand—
Tavernier, R.
Liege—
Calembert, Leon M. C.

Louvain—
Ubaghs, Georges J.
Gullentops, Frank B.

BRAZIL

Salvador—
Brantly, John E., Jr.
Weber, Rolf

BRITISH COLUMBIA

Vancouver—
Danner Wilbert R.

COLOMBIA

Bogota—
Maurenbrecher, A. L. F. J.
Petters, Viktor
Pickett, C. Rodman
Polson, Irving L.
Rominger, Joseph F.
Schoonover, Jack G.
Walker, Bruce H.

CUBA

Havana—
Acosta-Gimenez, Jose T.
Pardo, Georges
Truitt, Paul B.

ECUADOR

Guayaquil—
Galliers, John A.
Quito—
McLaughlin, Donald H.

EGYPT

Alexandria—
Higazy, Riad A.
Nakkady, S. E.
Cairo—
Arni, Paul
Eicher, Donald B.
Said, Rushdy
Samaan, Sobhi M.
Souaya, Fernand J.

ENGLAND

Bristol—
Loupekine, I. S.
Cambridge—
Allen, Percival
Leicester—
Whitaker, J. H. M.
Liverpool—
Bathurst, Robin
London—
Greensmith, John Trevor
Pyre, Augustin
Tenterden—
MacFadyen, W. A.

FORMOSA

Taiwan—
Stach, Leo W.

FRANCE

Bordeaux—
Burollet, P. F.
Vigneaux, Michel
Bourg-la-Reine—
Riviere, A.
Dijon—
Ciry, Raymond Maurice
Jouyen-Josas—
Jullian, Y.
Nancy—
Avias, Jacques
Paris—
Bourcart, J. J.
Cuvillier, Jean
Vatan, A.

GERMANY

Celle—
Wick, Werner
Freiburg—
Illies, Jurgen H.
Göttingen—
Correns, Carl W.
Hannover—
Bentz, Alfred
Fuchtbauer, Hans
Munich—
Hagn, Herbert

INDIA

Madras—
Kasthuri, A. K.
Mysore—
Gowda, S. Sambe

IRAQ

Baghdad—
Bettinger, Charles E.
Kirkuk—
Dunnington, Harold V.

IRELAND

Belfast—
Schwarzacher, Walther

ITALY

Cagliari—
Caria, Ida
Ferrara—
Leonardi, Piero
Florence—
Merla, Giovanni
Modena—
Gallitelli, E. Montanaro
Naples—
Mirigliano, Giuseppe
Palermo—
Alliata, Enrico
Cipolla, Francesco
Folk, Stewart H.
Ogniben, Leo
Pisa—
Trevisan, Livio
Rome—
Flores, Giovanni
Marchetti, Marco P.
Sander, Nestor J.

JAPAN

Fukuoka—
Toriyama, Ryuzo
Kyoto—
Makiyama, Jiro
Osaka—
Chiji, Manzo
Sendai—
Hanzawa, Shoshiro
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JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 2, P. 443, MARCH 1956

# NOTICES

## FIELD TRIP TO FAMOUS MIOCENE LOCALITIES IN PANHANDLE FLORIDA

The Florida Geological Survey will conduct a field trip for the Gulf Coast Section, Society of Economic Paleontologists and Mineralogists, under the leadership of Harbans S. Puri and Robert O. Vernon. The type Miocene localities in Panhandle Florida are to be visited. Participants will have sufficient time to collect the various sections.

Headquarters for the trip will be Tallahassee, Florida. Registration in Tallahassee is to be during the afternoon and evening of Thursday, May 3, at the Duval Hotel. A panel discussion of the Miocene sediments will be held on the evening of May 3. Further details can be obtained from the Survey, Box 631, Tallahassee, Florida.

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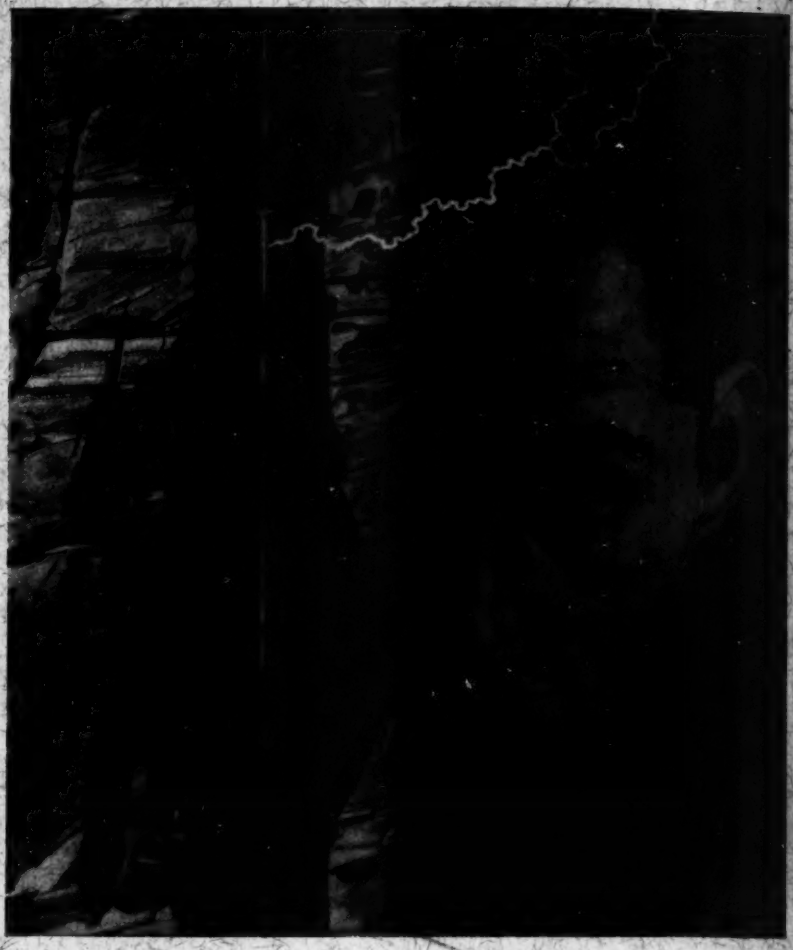

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